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Effect of Swine Manure Pit Additives and Facility Disinfectants on the Fate of Antibiotics and Manure Composition During Simulated Swine Manure Slurry Storage

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EFFECT OF SWINE MANURE PIT ADDITIVES AND FACILITY DISINFECTANTS

ON THE FATE OF ANTIBIOTICS AND MANURE COMPOSITION

DURING SIMULATED SWINE MANURE SLURRY STORAGE

by
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This thesis investigates the effect of time and of swine manure slurry treatment on the physical properties, nutrient content, and the concentrations of antibiotics chlortetracycline, lincomycin, and tiamulin in simulated storage of swine manure. In one experiment the slurry was treated with six additive products. In a second experiment a set of four disinfectant products were used. Control consisted of unamended slurry. Manure was stored in 60 liter stainless steel bioreactors to simulate deep pit storage and was sampled 7 times over a 40 day incubation.

From an ANOVA of the results, it was concluded that evaporation may be contributing a significant effect in concentration change of the manure constituents. With this in mind, each time series was normalized by its final time point and a second ANOVA was performed along with a growth curve analysis on the means and slopes over time of the normalized data. This further analysis resulted in a large decrease in treatment effects in the additives experiment but demonstrated no reduction in treatment effects in the disinfectants experiment.

With the additives experiment the *Coban 90* treatment produced an increase in mean total suspended solids relative to the control. Five of the additive products produced a slower decrease in electrical conductivity relative to the control. Only one

additive treatment was found to produce a greater mean tiamulin concentration relative to the control over the course of the experiment.

With the disinfectants experiment, two treatments increased mean concentrations of total nitrogen. Another two treatments caused an increase in mean phosphorus concentration. Once again, only one treatment produced an increase in mean tiamulin concentrations. The antibiotics concentrations reported in both experiments were highly variable and could not be fit accurately to decay models.

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Chapter 1: Literature Review

1.1 Background and Motivation for Study

According to the World Health Organization (2018), "antibiotic resistance is one of the biggest threats to the global health, food security, and development today. Misuse of antibiotics in the human health sector has played a large part in the acceleration of the development of antibiotic resistance, however antibiotics use in livestock production plays a significant role as well (Silbergeld, et al., 2008).

In 2016, 14.0 million kilograms of antimicrobial drugs were sold for use in livestock production in the United States (FDA, 2016). These antimicrobials may be administered to livestock for therapeutic purposes, but may also be dispensed at sub-therapeutic levels for prophylaxis and/or growth promotion. It is believed the use of antimicrobials for non-therapeutic purposes has greatly contributed to the proliferation of antimicrobial resistance (Chantziaras et al., 2013; Economou et al., 2016) . This constitutes a health risk for humans, especially when 'medically important' antibiotics – those which are used for human health benefit – are also used for livestock production.

Bacteria and other zoonotic pathogens can be transferred from livestock to humans via several pathways. Direct contact, exposure to agricultural operations, exposure to manure or manure runoff, consumption of contaminated food products, and inhalation of air-borne particles have all been demonstrated as pathways for transfer of resistance from animals to humans (Holmberg et al. 2007; McEachran et al. 2015; van Loo et al. 2007; Hoelzer et al. 2017). For example, a 1984 outbreak of ampicillin, carbenicillin, and tetracycline resistant Salmonella was shown to be caused by antimicrobials being fed to animals (Holmberg, et al. 1984). A 1999 outbreak of quinolone-resistant *Salmonella enterica* was shown to originate from a Danish swine herd which had been fed fluoroquinolones (Mølbak et al. 1999). Changes in the intestinal flora of farm personnel after introduction of antibiotics into an animal feeding regime have also been reported. A 1976 study demonstrated the presence of at least 80% tetracycline resistant bacteria in 7 of 11 farm personnel exposed to the tetracycline regime as compared to 3 of 24 personnel not exposed to it (Levy et al. 1976).

Animal manure is a major source of both antimicrobial compounds and antimicrobial resistance genes (ARGs). Antibiotics and their metabolites present in excreta may accrue during storage of livestock manure. Development of resistance genes can also occur in production facilities. Antimicrobials and their associated resistance genes can then enter the environment via agricultural land application of wastes. Runoff and infiltration from agricultural fields or from production facilities may then facilitate the transport of the antimicrobials to soil, groundwater, and surface water systems. For example, Sapkota et al. (2007) found elevated levels of erythromycin, tetracycline, and clindamycin downgradient from a production facility than upgradient from the facility.

Detection of antibiotic residues in environmental water has been well documented. A 2018 study investigated surface water, ground water, and waste water treatment effluent for the presence of 18 antibiotics of concern. Results showed the presence of amoxicillin, ampicillin, clopidol, fenbendazole, flumequine, lincomycin, sulfadiazine, and trimethoprim at concentrations of 1.26 to 127.49 ng/L (Kim, et al., 2018). Antibiotic leaching and sorption to soil is also an area of concern and has been studied in laboratory settings and in the field. For example, in one lab study, sulfamethazine, and erythromycin showed the greatest leaching potential in subsurface soil while chloramphenicol, tetracycline, and norfloxacin showed less leaching potential, but persisted longer in surface soil (Pan, et al., 2016). Leaching of antibiotics into subsurface soil may also result in uptake of antibiotics to crops, providing another pathway for transfer of antimicrobial resistance to humans (Pan, et al., 2016).

A review summarizing the results of 108 studies from on antibiotics in lake water and 39 studies that reported on antibiotics in lake sediment, all conducted between 2002 and 2018 was released in 2018. The earliest of the papers reviewed (Nakata et al. 2002) reported on the discovery of 57 antibiotics in the water and sediment of Lake Ontario. In the review, median concentrations of four sulfonamide compounds were greater than 11 ng/L, while median concentrations of three tetracycline compounds, quinolones ofloxacin and norfloxacin, and five sperate macrolides and lincosamides, exceeded 17 ng/L, 10 ng/L, and 10 ng/L, respectively (Yang et al. 2018). In the same review, the meta-analysis of antibiotics in sediment showed that, of the 35 antibiotics detected, 21 had median concentrations between 1 and 10 ng/g, while 6 (three sulfanamides and three quinalones) had median concentrations less than 1 ng/L. Another eight had median concentrations greater than 10 ng/L. Roxithromycin was detected at a high concentration of 302 ng/g in Baiyangdian Lake, China (Li et al., 2012). Sulfamethoxazole, sulfamerazine, sulfameter, tetracycline, oxytetracycline, erythromycin, and roxithromycin were all found at high concentrations in both water and sediment (Yang et al., 2018). A 2017 review also studied the presence of antibiotics in lakes, this time only in China. Results of the meta-data analysis revealed 39 different antibiotics detected in lake water (Liu et al. 2017).

A review of antibiotics in European environmental water found 73 different antibiotically active agents in wastewater influent and effluent, river water, lake water, and groundwater (Carvalho et al. 2016). In general, antibiotic concentrations in wastewater samples (including hospital wastewater) were found as high as several μg/L, concentrations in river water were in the range of tens and hundreds of ng/L, and less than 10ng/L were identified in groundwater (Carvalho et al. 2016). Thus, it appears that the antibiotic concentrations tended to decrease from wastewater, to river water, to lake water, and finally to ground water. Given the prevalence of antimicrobials in the environment and the proliferation of antimicrobial resistance as a result, more research needs to be performed regarding mechanisms of antimicrobial transfer to the environment from both municipal and agricultural sources.

This thesis describes the investigation of the effects of six swine manure pit additives and four common swine production facility disinfectant products on the concentrations of antibiotics in the swine manure slurry and on the chemical and physical characteristics of the slurry during simulated deep pit storage. During storage, manure pit additive products may be added to aid solids digestion, preserve manure nutrients, and reduce odor, foaming, and/or crusting of the manure. Surface disinfectants are commonly used to sanitize swine production facilities between production cycles or during mitigation of a disease outbreak. Thus, manure slurry stored in a deep pit may contain these products which can influence the degradation or persistence of antimicrobial residuals.

1.2 Antimicrobial Degradation During Storage

Swine production accounts for a large portion of antimicrobial usage in the United States. Of the total 14.0 million kilograms of antibiotics sold for livestock production, 25% (3.6 million kilograms) were used for swine production. Of medically important antibiotics given to livestock, 3.1 million kilograms were given to swine, accounting for 22% of all livestock antibiotics usage in that year. Tetracyclines, macrolides, and lincosamides were the three most commonly used antibiotics in the swine industry, at 2.5, 0.34, and 0.12 million kilograms each, respectively (FDA, 2016).

Little research has been conducted addressing the effect of manure pit additives or facility disinfection products on the fate of antibiotic compounds during swine manure slurry storage. However, work has been performed on the fate of antimicrobials and their associated resistance genes during pit storage as well as during composting and lagoon treatment under selected conditions. Research has also been conducted on the persistence of antibiotics in agricultural soil and runoff following land application of manure slurry. Furthermore, research has been performed investigating the effect of manure additive products on gaseous emissions from manure and on the physical and chemical characteristics of the manure.

The fate of the antimicrobials chlortetracycline, tylosin, and bacitracin was investigated during simulated storage of swine manure slurry (Joy et al., 2014). In this study, fresh manure slurry was collected, diluted with water to create a 2:1 manure to water ratio, and stored in 100mL amber glass jars for a 40-day incubation. Initial measured concentrations were 10, 300, and 50 mg/kg (dry weight basis) of tylosin, chlortetracycline, and bacitracin F, respectively. First order degradation models were fitted to the decay of each antibiotic, with half lives of 1, 9.7, and 1.9 days measured for chlortetracycline, tylosin, and bacitracin F, respectively.

In a similar study the degradation of chlortetracycline and oxytetracycline at doses of 10, 50, and 100 mg/L each, were measured during a 21 day anaerobic incubation (Alvarez, et al., 2010). Chlortetracycline showed half-lives of 3.8, 3.2, and 4.1 days, while oxytetracycline demonstrated half-lives of 13.3, 15.4, and 11.9 days at concentrations of

10, 50, and 100 mg/L, respectively. The results for chlortetracycline are greater than, but comparable to those reported by Joy et al. (2014). Alvarez (2010) also found, however, that in an abiotic control assay, both compounds were very unstable, with total removal of both compounds by day 14. Thus, the anaerobic digestion appeared to have a stabilizing effect on the residuals. The half-lives of chlortetracycline reported by both Joy et al.(2014) and Alvarez et al.(2010) are comparable, ranging from 1 to 4.1 days.

The degradation of chlortetracycline and tylosin during anaerobic digestion of swine manure was investigated over a 216 day incubation by Stone et al. (2009). Temperature during this incubation was controlled to gradually increase from 10 to 20°C between days 0 and 56 to simulate the transition from winter to summer. Over the course of the incubation, the concentration of chlortetracycline decreased from 27.0 to 11.6 mg/L. The concentration of tylosin remained relatively stable until day 109 of the incubation after which it decreased from 30 to 0 mg/L Though the chlortetracycline degradation was not fit to a first order model, its degradation rate appears to be much slower than reported by Joy et al. (2014), who reported a half-life of 9.7 days.

While chlortetracycline and oxytetracycline appear to have half-lives on the order of several days to several weeks, doxycycline was found to persist throughout a 170-day incubation period, with a half-life of 120 days during anaerobic incubation and 91 days during digestate storage (Wodyasari-Mehta et al. 2016). Thus, even antibiotics in the same family of compounds may have drastically different half-lives during slurry storage.

In a 40-day study, anaerobic digestion under both thermophilic and psychrophilic conditions was applied to swine manure containing sulfadiazine, sulfamethizole, sulfamethoxazole, clarithromycin, erythromycin, and trimethoprim (Feng et al. 2017). Trimethoprim was reduced by more than 99.9% at both temperature conditions in the study. Results were quite variable among the included sulfonamides. No significant reduction was reported for sulfadiazine or sulfamethizole under thermophilic conditions and only a 26% reduction was reported for sulfamethizole under psychrophilic conditions, however 98.5 and 99.88% reductions were observed for sulfamethoxazole under thermophilic and psychrophilic conditions, respectively. For the macrolides clarithromycin and erythromycin, reductions by more than 36% were only found for erythromycin under thermophilic conditions. Thus, high variability was observed in degrees of degradation among assorted antibiotics, indicating that a single microbial community may have more difficulty degrading some compounds than others.

Other methods of manure storage include composting and lagoon storage. Degradation of sulfadiazine, chlortetracycline, and ciprofloxacin during composting of swine manure was investigated by Selvam et al. (2011). The compost was created by mixing saw dust with manure at a 1:1 dry weight (dw) ratio and aerating the mixture at a rate of 0.5 L/kg_{dw} dry weight per minute. Compost was incubated over 56 days. The temperature of the compost peaked at 65°C during the first day of the incubation and slowly decreased to

30°C over the next 55 days. Antibiotics were spiked into the compost at 5 mg/kg_{dw} and 50 mg/kg_{dw}. Results showed that chlortetracycline and sulfadiazine were completely degraded by 21 and 3 days, respectively, regardless of the initial spiked concentration. Ciprofloxacin persisted for the entire incubation, though 17 and 31 percent of spiked ciprofloxacin was degraded for high and low dosages, respectively. Thus, composting may be an effective method of antibiotic degradation for chlortetracycline and sulfadiazine. Although half-lives were not reported in this study, the degradation of chlortetracycline is comparable to that reported by both Joy et al. (2014) and Alvarez (2010).

The degradation of tylosin and its metabolites has been investigated in both aerobic and anaerobic lagoons (Kolz et al., 2005). Tylosin followed a biphasic degradation pattern (a high initial degradation phase followed by a slow degradation phase). In both aerobic and anaerobic studies, 90% degradation was achieved in fewer than 5 days. In the anaerobic study, the residual tylosin after the first degradation phase remained for the duration of the incubation. In the aerobic study the second phase degradation continued until less than 1% of tylosin remained at the end of incubation. Metabolites tylosin B and D, which retain antibiotic activity, were also measured and remained in the slurry after eight months. This indicates that antibiotically active tylosin metabolites will enter the environment with land application of lagoon effluent, as will the parent compound if the slurry is anaerobically digested.

The fate of monensin has also been investigated during anaerobic digestion of dairy manure (Arikan et al., 2018). Monensin is the active ingredient in *Coban 90*, one of the additives studied in this thesis, but also has antibiotic activity. Field scale reactors with a 2 m^3 working volume were initially filled with non-amended manure in a plug flow configuration with hydraulic residence time of 17 d. Manure amended with 1 and 10 mg/L of monensin was then fed to the reactor and the effluent concentrations were measured over a 56 day incubation. Results showed that, at steady state, monensin concentrations in the reator were 70% lower than influent concentrations. Thus, while anaerobic digestion does reduce the concentration of monensin residuals, it does not completely degrade them.

The fate of monensin in cattle manure and chlortetracycline in swine manure during anaerobic digestion was also investigated to determine the effect of temperature (Varel et al., 2011). Anaerobic reactors were prepared at 22, 38, and 55 °C. Results showed that at 38 and 55°C, chlortetracycline concentrations were reduced by 80 and 98 percent, respectively. Meanwhile, the digestion at 22 °C only decreased chlortetracycline concentration by 7 percent. Degradation of monensin in the cattle manure was less apparent. At 55°C only 8 and 27 percent of monensin degraded at 38 and 55 degrees, respectively. Half-lives of monensin were determined to be 14.7 to 30.1 days whereas half-lives of chlortetracycline were determined to be 5.1 to 8.4 days, depending on temperature. The degradation of monensin reported in this study is significantly less than that reported by Arikan et al.(2018).

Research has also been conducted investigating the fate and transport of chlortetraytcline, tylosin, and bacitracin in agricultural soil and runoff following application of swine manure slurry under different application methods (Joy et al., 2013). Manure was land applied via broadcast, incorporation, and injection methods and the concentration of antimicrobials was determined in runoff and soil following three rainfall events. Broadcast application resulted in higher antimicrobial concentrations in runoff than when the manure was injected or incorporated; however results were not statistically significant due to large variability in measurements.

A similar study investigated the effect of narrow grass hedges on tylosin concentration in agricultural runoff (Soni et al., 2015). Plots were established to test the effects of narrow grass hedges, manure amendment, and number of rainfall events on the transport of tylosin in the runoff. The study showed that the presence of narrow grass hedges reduced the concentration of tylosin in runoff by over one order of magnitude. In those plots without a narrow grass hedge, dissolved concentrations of tylosin in runoff decreased over successive rainfall events. However, for plots with a narrow grass hedge, no trend was observed over three successive rainfall events.

1.3 Effect of Additives on Physical and Chemical Characteristics of Manure

Although no studies have been performed investigating the effect of manure additives on the persistence of antibiotics, research has been conducted regarding the effects of additives on other manure characteristics, such as gaseous emissions (especially ammonia) manure composition, nutrient removal or preservation, and bacterial diversity. No studies appear to have been published describing the effect of disinfectant products on either antibiotics fate or manure composition.

Research on manure additives has focused mainly on odor control and greenhouse gas emission reduction from stored animal manures. Additives designed for these purposes fall into several categories, including acidifiers, adsorbents, urease inhibitors (in the case of ammonia), oxidizing agents, and disinfectants. Additives have also been developed under the category of digestive additives, where bioaugmentation of the manure slurry is achieved through the addition of enzymes or selected microbial strains. These products are aimed at enhancing the biodegradation of manure, even to the point of replacing processes such as composting, aeration, or anaerobic digestion (McCrory et al., 2001). As a whole, these products appear to be ineffective at odor control, ammonia emission reduction, and total solids reduction, as summarized in a review by McCrory et al. (2001).

Much research has also been performed regarding the effects of selected inorganic and biological additives on biogas production from animal and human wastes. Inorganic additives designed to aid biogas production may include nutrient supplements, ashes from organic waste incineration, ammonia inhibiting compounds, and substances with high biomass immobilization capacity. Meanwhile, organic additives tend to be microbial inocula having hydrolytic or methanogenic activity, or enzymes to enable organic matter solubilization (Romero-Guiza, et al., 2015).

The effects of activated sludge and the biological additive sporzyme on manure nutrient content have been investigated with and without aeration (Zhu, et al., 2005). Manure was incubated over a 15-day period in cylindrical reactors. The experimental design of the study included five scenarios; 1) control with no additive or aeration, 2) only aeration, 3) aeration with sporzyme, 4) aeration with non-inoculated activated sludge, and 5) aeration with inoculated activated sludge. After one day of aeration, all aerated treatments experienced an approximately 41.5% decrease in total soluble phosphorus concentration and a corresponding increase in total insoluble phosphorus concentration. The decrease in total soluble phosphorus concentration was due to decreases in both soluble organic and inorganic phosphorus. Total Kjeldahl nitrogen concentration decreased by approximately 40% in all treatments except the control. These results indicate that aeration is an effective method of reducing both soluble phosphorus and nitrogen content of swine manure. Aeration may be expensive, however, so it would be desirable to see the effect of the additives on a slurry consisting primarily of anaerobic microbes.

One study investigated the effect of two biological or chemical based manure additives on manure solids and nitrogen composition (Holly et al., 2016). Additives *More Than Manure* (also investigated in this thesis) and *Pro-Act Biotech* were used to independently amend dairy manure slurry. Both additives were tested at their manufacturer recommended dosages as well as at 25 times and 10 times the recommended rate for *More Than Manure* and *Biotech*, respectively. Biotech was also coupled with an aeration treatment at both dosage levels. None of the *More Than Manure* or *Biotech* treatments produced significant reductions in the solids content of the manure slurry or total kjeldahl nitrogen, total ammonia nitrogen, organic nitrogen, or total carbon.

The separate and combined effects of *More Than Manure* amendment, anaerobic digestion, and coarse solids on the solids and nitrogen content of dairy manure were examined by Sun et al. (2014). Addition of *More Than Manure* to anaerobically digested manure did not produce a statistically significant change, either with or without coarse solids addition. Addition of *More Than Manure* to raw manure slurry with coarse solids present resulted in statistically significant increases in total nitrogen, total solids, and volatile solids. Addition of *More Than Manure* to raw manure with no coarse solids present resulted in a statistically significant increase in total solids and decrease in volatile solids.

The effect of temperature and an unnamed microbial additive on both swine and dairy manure was reported by Matulaitis, et al. (2013). Fresh liquid cattle and swine manure was collected and distributed into twenty-four 2.1 L buckets, half of each type of manure was dosed with 20 mL of additive and half with 20 mL of deionized water. Triplicates of each manure type and treatment were then placed into temperature controlled rooms at 5, 15, and 25 °C. The use of microbial additive did not change the characteristics of the manure and did not result in a change in volume of gaseous emissions (ammonia, methane, hydrogen sulfide, carbon diozide, carbon monoxide, and nitric oxide) between the amended and unamended manure. However, the use of the microbial additive tended to reduce ammonia emissions while increasing methane, carbon monoxide, and nitric oxide. An increase in temperature resulted in slightly greater gas production and emissions from the pig manure than from the cow manure.

The effect of a biological additive, BACTYcomplex, on nitrogen losses during storage of swine manure slurry in a production facility has also been investigated (Provolo et. al, 2016). The additive was applied directly to treated pits while control pits were left untreated. Manure was sampled from a reception tank after mixing. All samples were analyzed for total solids (TS) and volatile solids (VS) content as well as total Kjeldahl nitrogen (TKN) and total ammonia nitrogen (NH_3-N). Results indicated that the additive was effective at reducing the TS concentration of the slurry but was not effective at reducing the nitrogen concentration. Changes in NH_3-N:TS and NH_3-N:TS were statistically significant; however, this was due to the degradation of organic matter rather than conversion of nitrogen forms in the manure.

Maleic-itaconic copolymers have been investigated as a urease inhibitor, which is purported to decrease production of ammonia nitrogen in manure. This copolymer is the active ingredient in the additive product *More Than Manure* which is investigated in this research. A review of the maleic-itaconic co-polymer in two other additive products, *Nutrisphere* and *Avail* was performed by Chein et al. (2013). *Nutrisphere* claims to reduce ammonia volatilization and *Avail* claims to reduce phosphorus losses due to de-solubilization (Chien et. al, 2013). *Nutrisphere* consists of urea coated with the copolymer and Avail is a water soluble phosphorus fertilizer coated with the copolymer. Chien et. al (2013) investigated the effectiveness of the copolymer based upon principles of soil chemistry and with field testing. Field testing consisted of mixing clay loam and sandy loam soils with urea as a control and with urea plus copolymer as a treatment. This study found neither product was able to perform as marketed. While it is important to note this experiment was carried out in soil, rather than manure, the findings incite some skepticism as to the effectiveness of the copolymer for nutrient retention. Another study by Goos (2013) found the additive *Nutrisphere* to have a minor effect of reducing ammonia volatilization from soil.

Despite the previous two studies by Chien et al. (2013) and Goos (2013), another study (Chein et al., 2013) found that the maleic-itaconic copolymer as formulated in the additive *More Than Manure* was able to significantly reduce ammonia volatilization in dairy manure. Experimental treatments consisted of a control with no *More Than*

Manure additive, and doses of 0.1, 0.4, 0.8, 1.8, and 6.2 mL/L manure. Ammonia gas production was measured over a 24 hour period. For one batch of manure all treatments but the 0.1mL/L concentration produced significant changes in ammonia gas production by the end of the 24 hour incubation. For a second batch of manure all treatments were significant over the 24 hour incubation. This indicates that in manure, the maleic-itaconic copolymer may be effective at urease inhibition. In manure, urea concentration will be significantly higher than in soil, which may be why significant results were found by Chen et al., (2013) but not by Chien et al. (2014) or Goos (2013).

Chapter 2: Materials and Methodology

2.1 The Additives and Disinfectants

In this study six manure pit additive products (*Coban 90, Manure Magic, MOC-7, More Than Manure, Sludge Away, and Sulfi-Doxx*) were tested. Pit additives are marketed for several purposes. Common additive goals are solids reduction, crust prevention, odor control, foam reduction, and nutrient preservation. Although there is often one primary function of an additive, they are often marketed as multi-purpose products.

Elanco produces *Coban 90* which. is designed as a feed additive for chicken, turkey, and quail to prevent coccidiosis (an intestinal ailment). *Coban 90*, and similar products such as Rumensin 90, which shares the same active ingredient of Monensin, has been co-opted by the swine industry as a method of pit foam control (Coban, 2018). Although this off-label use is technically illegal, producers have continued to use it as a method of pit foam control (Clanton, 2012). A small sample of *Coban 90* was obtained for this study through the Veterinary Diagnostic Center on the campus of the University of Nebraska, Lincoln.

Manure Magic which is marketed as a solution to solids, foaming, odor, and other nuisance issues in pits and lagoons is produced by Drylet Information on the active ingredients of *Manure Magic* was not available. *Manure Magic* was purchased through a regional distributor of Drylet.

MOC-7 is a product of Ag Odor Control and it is primarily used for odor reduction, but is also marketed as helping to reduce solids buildup and crust formation. Active ingredients of *MOC-7* are proprietary to the manufacturer. *MOC-7* was purchased from a regional distributor of Ag Odor Control.

Verdesian Life Sciences manufacture *More Than Manure*. It is primarily marketed as a nutrient management product, however it is also used to reduce ammonia emissions. *More Than Manure* is designed to diminish phosphorus losses and reduce nitrogen losses due to volatilization, leaching, and denitrification. It is also marketed as being able to reduce solids. The active ingredient in *More Than Manure* is a Maleic-itaconic copolymer with partial calcium and ammonium salts (*More Than Manure*, 2018). *More Than Manure* was purchased through a regional representative of Verdesian.

Sludge Away is manufactured by Ecological Laboratories and it is marketed to reduce organic solids and to diminish the biogases produced during anaerobic digestion of manure. *Sludge Away* is primarily marketed to owners of ponds to aid in the breakdown of bottoms solids, eliminating the need to dredge or vacuum. It also helps to prevent release of potentially harmful gaseous compounds. *Sludge Away* is also used by the swine industry for these same reasons. *Sludge Away* utilizes humic acid based lignins which absorb odorous compounds and utilizes strains of purple sulfur bacteria to sequester volatile sulfur containing compounds (*Sludge Away*, 2018). *Sludge Away* was purchased from Fishman's, a local landscaping company in Lincoln, NE.

Direct Biologicals and manufactures *Sulfi-Doxx* which it is produced to control the emission of hydrogen sulfide and is marketed as an ingredient for odor control. Sufli-Doxx is a mixture of bacillus bacteria and Trichoderma fungus in a humate liquid carrier (Direct Biologicals Safety Data Sheet, n.d.). *Sulfi-Doxx* was purchased from a regional representative of Direct Biologicals.

Four facility disinfectant products (*Clorox*, *Pi-Quat*, *Tek Trol*, and *Virkon*) were tested. A disinfectant is a chemical agent applied to inanimate objects which inactivates or destroys microorganisms. Disinfectants serve to reduce the disease challenge to the herd, improve animal health and welfare, and increase the growth an efficiency of the herd.

Clorox Bleach is a halogen based disinfectant. It is used for a variety of purposes inside and outside of the animal production industry. *Clorox* was purchased from Target. It's active ingredient is sodium hypochlorite.

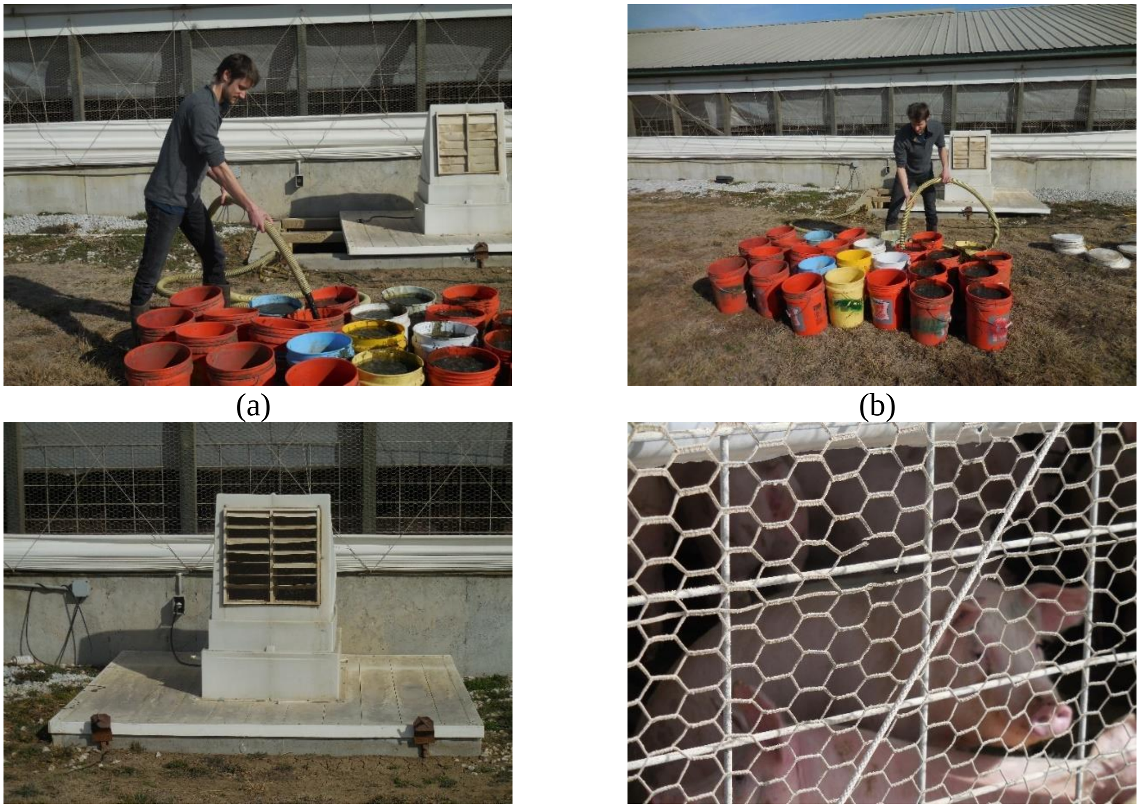
Pi-Quat is a quaternary ammonium cation based product commonly used in the animal production industry during cleaning and sanitation of production facilities. It's active ingredients are alkyl dimethyl benzyl ammonium chloride (10%), alkyl dimethyl ethylbenzyl ammonium chloride (10%), and inert filler (80%) (*Pi-Quat* 20, n.d.). *Pi-Quat* was purchased from QC Supply.

Tek Trol is a phenol based disinfectant. It's active ingredients are para-tertiary-Amylphenol, ortho-benzyl-para-chlorophenol, and ortho-Phenylphenol. It is used for sanitation of Staph, E. coli, rotovirus, adenovirus, and others (*Tek Trol*, n.d.). *Tek Trol* was purchased from QC Supply.

Virkon is an oxidant with active ingredients potassium peroxymonosulfate (21.41%), sodium chloride (1.50%), and other ingredients (77.09%) (*Tek Trol*, n.d.). *Virkon* was purchased from QC Supply.

2.2 Manure Collection and Storage

Slurry used in this study was collected from a production facility near Dorchester, Nebraska. Slurry was obtained for the first portion of the study on the 10^{th} of October 2017. The slurry was collected from a deep pit of the production facility via a ventilation duct located on the outside of the building. A sump pump lowered into the pit pumped the slurry into 19 L buckets (Figure 2.1). Approximately 687 L of slurry was required for the additives experiment and 490 L was needed for the disinfectants experiment. Slurry was then immediately transferred to the 57 L stainless steel pots in which the experiments were conducted.



(a) (b) (c) (d)

Figure 2.1: Slurry was collected in 19 L (a and b) buckets from the pit of a commercial swine production facility via a ventilation duct on the exterior of the building.

The simulated manure storage took place in a hoop house style greenhouse on the East Campus of the University of Nebraska - Lincoln. The hoop house was temperature controlled in both the summer and winter. The heating ducts ran down the floor of each side of the hoop house from back to front. Cool air entered from two ducts in the back of the facility. Fans located in the front of the hoop house directed air movement from the back to the front of the structure.

The manure slurry was stored in 57 L stainless steel stock pots which served as reactors. Each pot was filled with approximately 50 L of slurry. The reactors were located in the back of the greenhouse, in front one of the cool air ducts. Figure 2.2 shows the arrangement of the reactors in relation to the cool air duct and to each other.

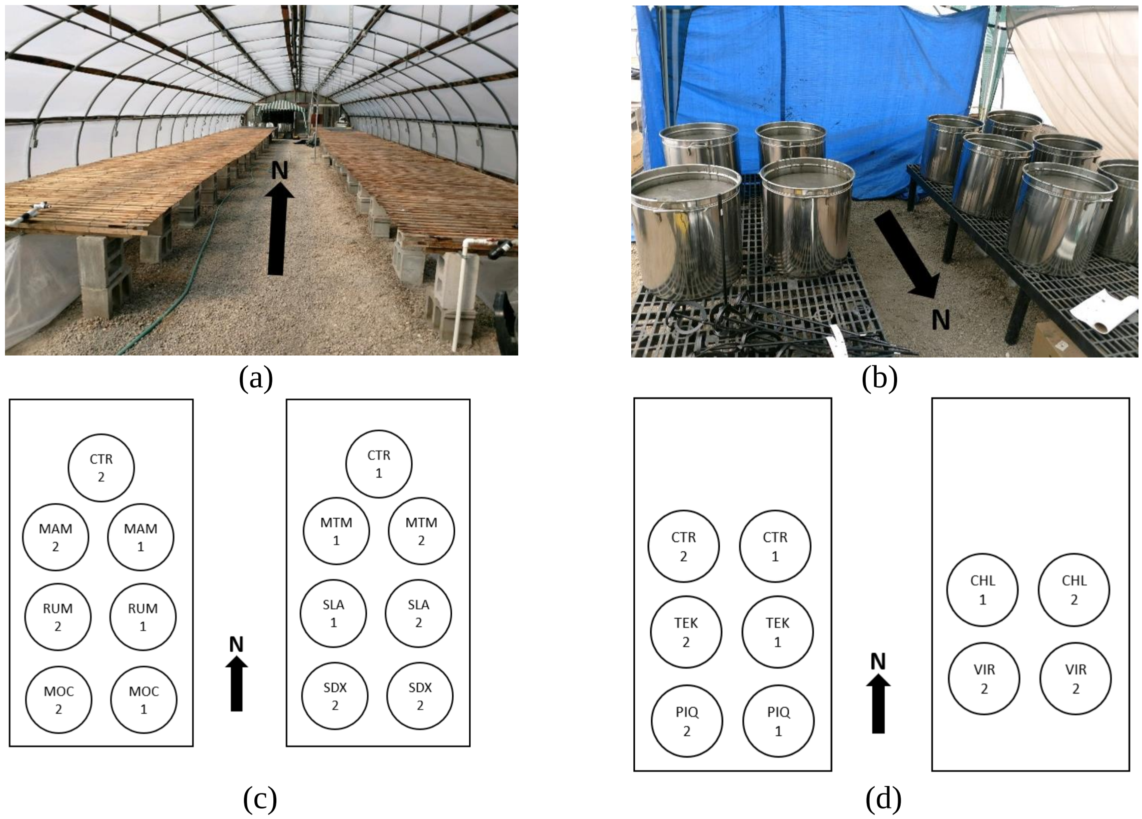


Figure 2.2: (a) A view of the hoop house standing at the entrance on the south side of the hoop house. The awning can be seen at the far north end of the hoop house. (b) A view of the reactors with slurry at the beginning of the disinfectants experiment. (c) A schematic of the reactor arrangement for the additives experiment. (d) A schematic of the reactor arrangement for the disinfectants experiment.

An awning covered the reactors, keeping direct sunlight from the manure. A tarp wrapped around the outside of the awning provided additional protection from sunlight and helped to make the amount of sunlight received by each reactor more uniform. Before the start of the study, the temperature effects of reactor placement in the greenhouse was investigated to ensure the temperature of each reactor was approximately the same. Two tarps were wrapped around the south and west faces of the awning to ensure uniformity of direct sunlight received by all reactors.

2.3 Dosing of Additives and Disinfectants

The dosing of both pit additives as well as pit disinfectants was calculated for the manure slurry reactors. Dosing for additives was determined from the manufacturers' literature or instructions as well as from personal correspondence with the manufacturers of the additives. Dosing of the disinfectants was determined by calculating the volume necessary to achieve surface saturation of the internal surface area of the reactors at the desired concentration. See Table 2.1 for a full summary of the dosing calculations for additives and disinfectants.

The additive products are typically used at a much larger scale than was needed for this study. With *Sludge Away*, *Sulfi-Doxx*, *Coban 90*, and *Manure Magic*, the application rate given as volume or weight of product per volume of manure slurry was taken from product literature and scaled down to 13 gallons of manure slurry. With *More Than Manure*, the dosing amount was determined by assuming a nitrogen requirement for an acre of corn, and by determining the nitrogen content of the manure slurry, calculating an amount of *More Than Manure* to be dosed. This calculation is shown in Equation 1. Ag Odor Control, the manufacturer of *MOC-7*, typically works with producers to determine dosing requirements for a specific facility. However, *MOC-7* engineers were able to determine that for an approximately 15-gallon pit of manure, 6 oz. of their product would be required.

$$\left(\frac{5{,}883 mg\ N}{L\ slurry}\right)\left(\frac{kg}{1E6mg}\right)\left(\frac{hectare}{151kg\ N}\right)\left(\frac{18\ oz.MTM}{acre}\right)\left(\frac{2.47\ acre}{hectare}\right)\left(\frac{L}{33.8\ oz.}\right)\left(\frac{1000L}{mL}\right) = 0.05\,\frac{mL\ MTM}{L\ slurry} \qquad \text{Eq. 1}$$

To calculate the dosing of the disinfectant products a different approach was required. In a production facility, the amount of disinfectant used depends on the surface area being cleaned. Typically surface area is roughly estimated by multiplying the floor space by 2.5 to account for walls and other areas in need of disinfection. Then the surface area is multiplied by a depth of 0.03 cm, which is the depth required for surface saturation. If a rinse is recommended by the manufacturer, an equal volume of rinse water is added with the disinfectant product. In this experiment, to maintain consistency in volume of the treatments, if a rinse was required than the disinfectant product dose was reduced by half and the difference made up with the rinse water. *Tek Trol* and *Chlorine Bleach* recommended rinse while *Pi-Quat* and *Virkon* did not.

The area of the base of the reactors are 0.47 square meters. Multiplying by 2.5 to account for walls and other surfaces yields 1.18 square meters. At a depth of 0.03 cm, a volume of 350 mL is required for disinfection. This calculation is provided in Equation 2.

$$(0.47m^2)(0.0003m)(2.5)\left(\frac{1{,}000{,}000mL}{m^3}\right) = 350mL \qquad \text{Eq. 2}$$

Thus for *Tek Trol* and *Virkon* a dosage of 175mL of product and 175 mL of water was used and for *Chlorine Bleach* and *Tek Trol* and dosage of 350 mL of product was used.

Table 2.1: Dosing requirements for pit additives and disinfectants.

Product	Manufacturers Dosing Requirement	Prepared Dose	Concentration in Slurry
		Pit Additives	
Coban 90	2.27 kg per 378,541 L manure slurry[1]	0.295 g product	6.0 mg/L slurry
Control	NA	NA	NA
Manure Magic	22.7 kg per 3,785,410 L manure slurry[2]	0.295 g product	6.0 mg/L slurry
MOC-7	177 mL per 56.8 L manure slurry[3]	1.7 mL product	3.0 mL/L slurry
More Than Manure	215 mL per ha. of manure land application[4]	3.1 mL product	0.05 mL/L slurry
Sludge Away	5.68 L per 28,391 L manure slurry[5]	9.8 mL product	0.20 mL/L slurry
Sulfi-Doxx	3.79 mL per 56,781 L manure slurry[6]	0.82 mL product	0.067 mL/L slurry
		Disinfectants	
Control	NA	360 mL DI Water	NA
Clorox	Surface Saturation[7]	180 mL product + 180 mL DI Water	1.7 mL/L slurry
Pi-Quat	Surface Saturation[7]	360 mL product	3.4 mL/L slurry
Tek Trol	Surface Saturation[7]	180 mL product + 180 mL DI Water	1.7 mL/L slurry
Virkon	300 mL/m^2 [7]	1.80 g of product in 360 mL DI Water	3.4 mL/L slurry

1: (Clanton, 2012)
2: (Manure Magic Application Instructions, n.d.)
3: (Totejoy, 2017)
4: (More Than Manure Nutrient Manager, n.d.)
5: (Microbe Lift / SA, n.d.)
6: (Microbe Lift: Advanced Microbial Manure Treatment, n.d.)
7: (Schmidt, 2017)

2.4 Manure Sampling

Manure was retrieved from the reactors using a 500mL container. Dedicated containers were used for each reactor. Prior to sample retrieval from the reactors, each reactor was stirred using a large cast iron paint stirrer operated with a cordless power drill. The manure slurry was stirred with the paint mixer for 30 seconds or until the foam crust on the top of the manure was completely incorporated into solution. A dedicated mixer was used for each reactor.

Table 2.2: Schedule of sampling, additives and disinfectants experiments

Days Since Dosing	Date	Time of Collection	Time into Storage
	Additives Experiment		
Manure Collected from Facility	01/18/2018	NA	NA
0 (Baseline)	01/25/2018	15:00	16:00
1	01/26/2018	16:00	19:00
2	01/27/2018	15:30	18:45
5	01/30/2018	15:00	18:00
10	02/04/2018	12:00	15:15
14	02/08/2018	15:00	18:00
21	02/15/2018	16:00	19:15
32	02/26/2018	17:00	20:15
40	03/06/2018	15:00	17:45
	Disinfectants Experiment		
Manure Collected from Facility	03/27/2018	NA	NA
0 (Baseline)	03/30/2018	15:35	16:30
1	04/01/2018	15:00	17:30
2	04/02/2018	17:00	19:15
5	04/05/2018	16:00	18:30
10	04/10/2018	15:00	17:15
14	04/14/2018	16:15	18:45
21	04/21/2018	12:00	14:00
32	05/02/2018	14:00	16:15
40	05/10/2018	16:30	18:30

After mixing, approximately 1 L of slurry was transferred from each reactor into clear plastic bottles which were immediately taken back to the lab. Once in lab, each 1 L sample was mixed for 30 seconds on high in a lab blender. After blending, each sample was distributed into smaller subsamples to be used for analysis of nutrients , antibiotics, antibiotic resistant genes (ARG), and physical properties of the manure slurry. Blenders were cleaned between processing of each sample by a thorough rinse, followed by sanitation with a solution of 50:50 by volume isopropyl alcohol to water solution which was allowed to remain on the surface of the blender for 30 seconds, followed by a second thorough rinse.

Samples to be analyzed for physical properties of the manure (total solids, total volatile solids, total dissolved solids, total suspended solids, and chemical oxygen demand) were stored in clear plastic bottles maintained at 4°C. These samples were analyzed within 48 hours of sampling. Samples to be analyzed for nutrients were stored in clear plastic bottles at 4°C out of light until the completion of the experiment, at which time they were all analyzed. Samples to be analyzed for antibiotics concentrations were stored out of light in amber glass bottles at -20°C until the completion of both experiments. All other samples were stored in plastic Eppendorf tubes at -20 °C out of the light until the completion of the experiments, at which time they were analyzed. Sampling dates and times of storage are recorded in Table 2.2.

2.5 Temperature, Dissolved Oxygen, and pH Measurements

High temperature, low temperature, dissolved oxygen, and pH were measured in the reactors at each sampling time point. Temperature was measured with a Fisherbrand™ Traceable™ Flip-Stick™ Thermometer. Dissolved oxygen and pH were also recorded at the time of sampling. These measurements were performed with a Thermo-Fisher Orion Star Water Quality Meter. The pH and dissolved oxygen probes were calibrated each sampling day before use with pH 4, 7, and 10 buffer solutions. The dissolved oxygen probe was calibrated using saturated air.

2.6 Chemical Oxygen Demand Testing

Chemical oxygen demand was performed on samples no more than 3 days after the sample collection. In most instances the analysis was performed within 24 hours. All samples waiting for COD analysis were stored in polypropylene bottles refrigerated at 4 °C. The samples were prepared by pipetting 0.25 mL of slurry from the polypropylene bottles into a 25 mL beaker. The slurry was then diluted by 20 by adding 4.75 mL of deionized water to the beaker. Then, 0.20 mL of diluted slurry was pipetted into a Hach High Range Plus COD Digestion Vial. Once all samples were prepared, the digestion vials were inverted several times to enhance mixing and added to a heating block at 150 °C for 2 hours. At the end of 2 hours, the heating block was turned off and allowed to cool to 120 °C before the vials were removed and allowed to cool. Once at room temperature, the vials were analyzed in a Hach DR 2800 Spectrophotometer using program 435 for HR COD. As per manufacturer instructions, the COD provided values were multiplied by 10 to convert from HR to HR+ analysis. This result was then multiplied by 20 to account for the factor 20 dilution.

2.7 Solids Testing

All samples for solids testing were stored in the same manner as previously described for COD analysis. Total solids, total volatile solids, total suspended solids, and total dissolved solids were measured. Total solids testing was performed by pipetting 8 mL of manure slurry into a tared 70 mm aluminum solids handling pan. The wet weight of the slurry was then recorded. The pan was transferred to a steam table for approximately 30 minutes until the slurry was dry. It was next transported to a 105 °F oven for at least 24 hours. The pan was then cooled in a desiccator and weighed again. This second weighing provided the moisture content of the slurry as well as the total solids content. After weighing, the pan was transferred to a 550 °F furnace for 30 minutes. After cooling again in a desiccator, the pan was weighed a final time, yielding the volatile solids content.

To find the suspended and dissolved solids content of the slurry, 0.25 mL of slurry was pipetted into a 25 mL beaker and diluted with 20 mL of distilled – ionized water. The diluted slurry solution was then filtered through a pre-weighed 47 mm glass fiber filter. If needed, an extra 5 mL of water was used to rinse any remaining solids from the beaker onto the filter. The filter was then placed into a 105 °F oven for at least 24 hours. Ten milliliters of filtrate were transferred to a tared aluminum solids handling pan and placed in a 105 °F oven for at least 24 hours to dry as well. The filtration apparatus is shown in Figure 2.3.

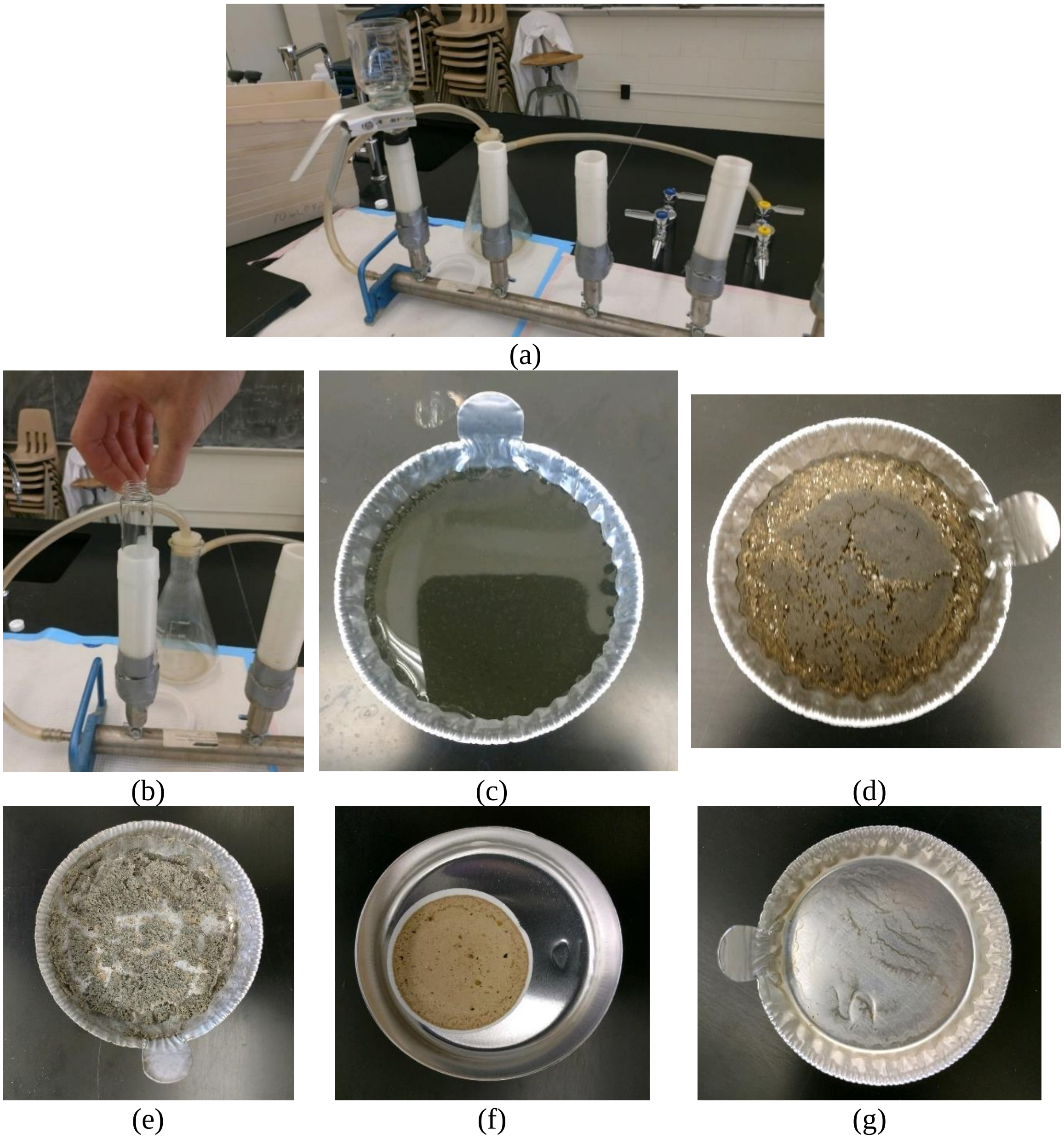


Figure 2.3: (a) The filtering apparatus for preparation of TSS and TDS. (b) The filtrate is collected in a glass vial located inside the filtering apparatus. (c) The manure slurry in a solids handling pan. (d) The dried manure slurry after removal from the oven; total solids. (e) The total volatile solids, after the pan is removed from the furnace. (f) The filter paper after drying, total suspended solids. (g) The dried filtrate after removal from the oven; total dissolved solids.

2.8 Nutrient Analysis

All nutrient analyses were performed by Ward Laboratories in Kearney, Nebraska using widely established analytical procedures.

2.9 Antibiotics Analysis

To prepare for extraction, 1 gram of each sample was weighed into a 40 mL plastic tube with 2 grams of clean sand. Then 0.5 grams ethylenediaminetetraacetic acid (EDTA) was added to the samples as a stabilizer. Samples were spiked with 100 µL of a surrogate spike and 100 µL of an analyte spike. Next, to each sample 14 mL of ammonium citric acid (100mM ammonium citrate and 4g/L ammonium acetate, adjusted to pH of 6, as a buffer and 6 mL of acetonitrile solvent was added. The plastic tubes were then shaken in a wrist action shaker for 30 minutes and centrifuged for 10 minutes before decanting into a RapidVap tube. After decanting, 4 mL of the above buffer and 16 mL acetonitrile were added to a RapidVap tube. Solvent was then evaporated until 18 mL of supernatant remained. Finally, 82 mL of 4 g/L ammonium acetate in water solution was added to each sample before extracting through an Oasis HLB (hydrophilic lipophilic balance) 6cc (200mg) cartridge which has been preconditioned with 5 mL of acetonitrile and 5 mL of de-ionized (DI) water. After all solution has been passed through, the HLB cartridge walls were rinsed with 5 mL of DI water and then dried for 5 minutes by pulling air on vacuum.

After the cartridges were dried, they were eluted with 6 mL of 1% by volume sodium acetate (1% ww) and 99% by volume acetonitrile solution. Once all eluent has passed through the cartridge, the cartridge was dried under vacuum. The eluent was then evaporated to dryness under a stream of nitrogen gas. Finally, all samples are spiked with 100 ng/µL of an internal standard solution before vortexing with 250 µL of 2 mM ammonium citrate and 150 µL of 10 g/L ammonium acetate solutions. Samples were then transferred to vials for analysis on a liquid chromatography mass spectrometer (LCMS).

With each batch of samples analyzed, a lab duplicate sample, lab fortified matrix sample, lab fortified blank sample, and lab reagent blank sample were also run for quality assurance and quality control.

2.10 Statistical Analysis

Both additive and disinfectant experiments were conducted with assumed complete randomization. Two bioreactors per treatment were used and each reactor was measured repeatedly over 40 days. Analysis of variance (SAS, 2011) for a randomized design with repeated measures over time was used to identify to effects of manure amendment and time on the persistence of antibiotics and on the characteristics of the slurry. The least significant difference test (LSD) was used to identify differences among experimental treatments. A probability of $P < 0.05$ was considered significant.

For the normalized data, a growth curve analysis on reactor means and slopes over time was used to characterize the overall mean differences and slope differences among treatments (Eskridge et. al, 1987). An LSD test was used to separate treatment means and slopes. An ANOVA was also performed on the normalized data to characterize statistically significant time effects at the 95% confidence level.

Chapter 3: Results

3.1 Overview of Data Processing

The analysis of the data presented in this thesis are aimed at isolating the effects of both time and manure amendment on the physical and chemical slurry characteristics and on the fate of antibiotics residuals. The data collected was first analyzed in SAS (2011) using ANOVA, as discussed in Sections 3.3-3.6. These results indicated substantial statistical significance between treatments, and especially, time. The extent of the uniformity in these initial results signaled perhaps time and treatment were not the only factors influencing the dependent variables.

It was hypothesized that evaporation from the experimental reactors may have created an artificial increase in the constituent concentrations in the slurry. To counter this effect, each data time series was normalized by the value of its last time point (day 40). Thus each normalized data series consisted of a series of fractional values with the final value being unity. Normalizing the data as such allows the effect of manure slurry treatment to be isolated from the effects of evaporation.

To determine the isolated effect of treatment on manure constituent, a growth curve analysis (Eskridge and Stevens, 1987) was performed on the slope and mean of each normalized time series. An LSD test was used to distinguish the slopes and means of each treatment from the control and from other treatments. If the series differs from the control with respect to either mean or slope, the treatment can be said to have had an effect. In other words, the concentrating effect of evaporation can be said to not be the only factor affecting change in constituent concentration. This method assumes the evaporation from each reactor is the same, or at the very least, that differences in evaporation between reactors are only due to slurry treatment.

In sections 3.3-3.6 of this chapter, the un-normalized data for physical and chemical properties of the manure slurry are presented. Section 3.7 addresses the un-normalized antibiotics data. Sections 3.8-3.11 address the ANOVA of the normalized physical properties and nutrient content data to determine the isolated effect of treatment on the slurry characteristics. Section 3.12 presents the effects of time and treatment with the normalized antibiotics data.

3.2 Baseline Manure Slurry Characteristics

The characteristics of the manure slurries collected for each of the two experiments, shown in Table 3.1, is consistent with that of manure analyzed for similar experiments in the literature. The manure was anaerobic (dissolved oxygen levels <0.1mg/L) and slightly basic.

Both slurries were very high in solids, though the slurry used in the disinfectants experiment had higher solids concentrations than that of the additives experiment. Total solids (TS) of the baseline slurry for the additives experiment was 66% that of for the disinfectants experiment (85,878 mg/L versus 57,200 mg/L). The other solids characteristics of the two slurries were consistent with the total solids. The total volatile solids (TVS), total suspended solids (TSS), and total dissolved solids (TDS) of the disinfectant experiment slurry was 56,121, 31,489, and 31,489 mg/L, respectively. With the additives experiment slurry these values were 60, 65, and 76% of the corresponding values in the disinfectants experiment.

Table 3.1: Baseline slurry characteristics, measured pre-dosing

	Additives Experiment	Disinfectants Experiment
pH	7.81	7.90
Dissolved Oxygen, mg/L	0.07	0.08
Total Solids, mg/L	57,200	85,878
Total Volatile Solids, mg/L	33,825	56,121
Total Suspended Solids, mg/L	35,400	54,350
Total Dissolved Solids, mg/L	23,996	31,489
Chemical Oxygen Demand, mg/L	66,200	82,600
Dry Matter, %	5.47	7.72
Electrical Conductivity, mS/m	28.22	27.84

Chemical oxygen demand (COD) and dry matter were also greater in the slurry used for the disinfectants experiment than for the additives experiment. All of these metrics indicate the disinfectants experiment manure slurry is between 20 and 40% thicker than the slurry used in the additives experiment. The only baseline characteristic in which the two slurries were equal was for electrical conductivity. The additive slurry measured 28.22 mS/m, while the disinfectant slurry measured 27.84 mS/m. This is an interesting result given the 24% difference in TDS of the two slurries.

The differences in solids and COD between the two slurries is most likely due to the date at which each slurry was collected from the production facility pit. The additives experiment slurry was collected in mid-January, when the production facility pit was mostly empty. The disinfectants experiment manure was collected in late March. At this time the pit was more full and had more time to build up solids from the animals, as well as for evaporation from the pit to naturally thicken the slurry.

3.3 Physical Manure Properties from Additive Experiment

Properties evaluated in this section include pH, dissolved oxygen (DO), chemical oxygen demand (COD), total solids (TS), total volatile solids (TVS), total suspended solids (TSS), and moisture content (MC). High and low temperature over the sampling period was also measured, however temperature was not considered to be a dependent variable.

An ANOVA over these physical manure properties was performed and the results are displayed in Table 3.2. In this analysis, both time and manure amendment are considered as variables. Time was statistically significant at the 95% confidence interval for COD, TS, TVS, and TSS and MC. Manure amendment was statistically significant for DO, COD, TS, TVS, TSS, TDS, and MC. An interactive effect between time and manure amendment was present only for pH. The time effects of the statistically significant constituents are shown in Figure 3.1 and the interactive effects of pH is shown in Figure 3.2.

Table 3.2: Results of the ANOVA of pit additive and time on physical characteristics of the manure slurry averaged over eight time points (Additive) and duplicate additive treatments (Time)

	pH	DO* mg/L	COD mg/L	TS mg/L	TVS mg/L	TSS mg/L	TDS mg/L	Moisture Content %
Additive								
Coban 90	7.86 d	0.06	50,290 cd	43,550 b	24,640 b	29,480 b	23,960	95.3 a
Control	7.89 cd**	0.05	47,200 d	41,920 b	22,950 b	24,410 c	25,070	95.6 a
Manure Magic	7.84 d	0.06	53,640 c	43,020 b	23,960 b	26,790 bc	24,550	95.5 a
More Than Manure	7.95 abc	0.09	71,150 a	59,040 a	33,850 a	43,800 a	25,000	93.8 b
MOC-7	8.00 ab	0.05	66,360 b	59,120 a	33,690 a	40,730 a	25,500	93.7 b
Sludge Away	7.93 bc	0.08	68,750 ab	58,540 a	33,660 a	42,210 a	25,210	93.5 b
Sulfi-Doxx	8.02 a	0.06	69,880 ab	58,460 a	33,630 a	44,230 a	25,420	93.7 b
Time (days)								
1	7.83	0.084	67,829	43,965	25,183	33,657	24,177	
2	7.95	0.069	70,571	42,099	24,003	29,763	19,519	94.8
5	7.83	0.056	57,286	53,779	31,306	35,669	23,663	
10	7.88	0.067	57,214	54,540	31,095	35,709	26,591	
14	7.87	0.074	59,857	51,296	28,624	35,871	16,119	95.5
21	7.95	0.046	58,514	56,250	31,814	41,194	29,814	95.6
32	8.00	0.051	59,814	57,390	32,038	38,743	31,723	95.6
40	8.11	0.046	57,214	59,551	31,095	35,709	28,054	94.9
ANOVA (P>F)								
Additive	0.01	0.18	**0.01**	**0.01**	**0.01**	**0.01**	0.99	**0.01**
Time	0.01	**0.04**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.03**
Additive x Time	**0.01**	0.77	0.06	0.32	0.49	0.58	0.78	0.44

*Abbreviations: Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Solids (TS), Total Volatile Solids (TVS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Moisture Content (MC).
**Values in the same column followed by different letters are significantly different at the 0.05 probability level based on the LSD test.

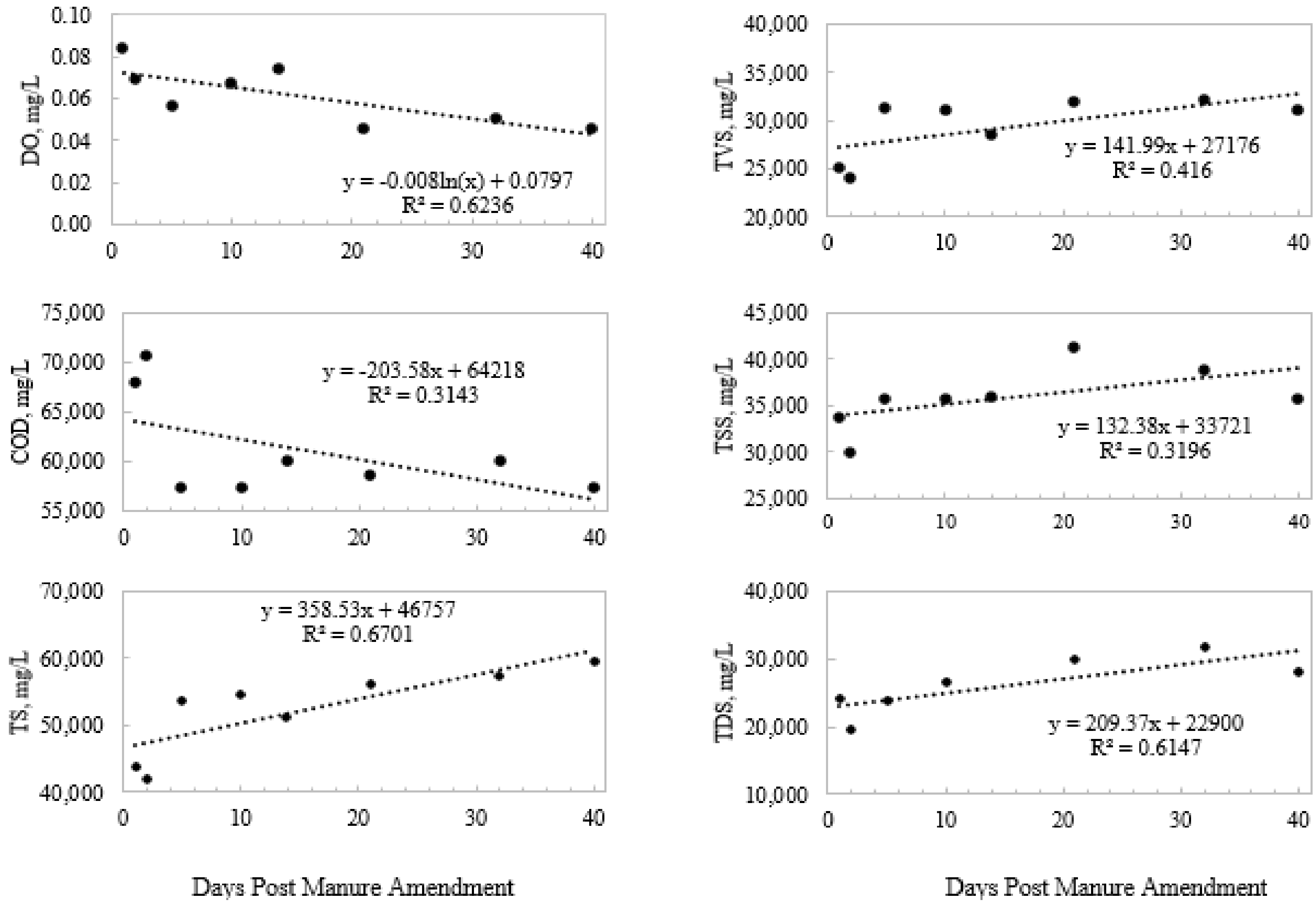


Figure 3.1: Time effects of physical properties of the manure in the additives experiment.

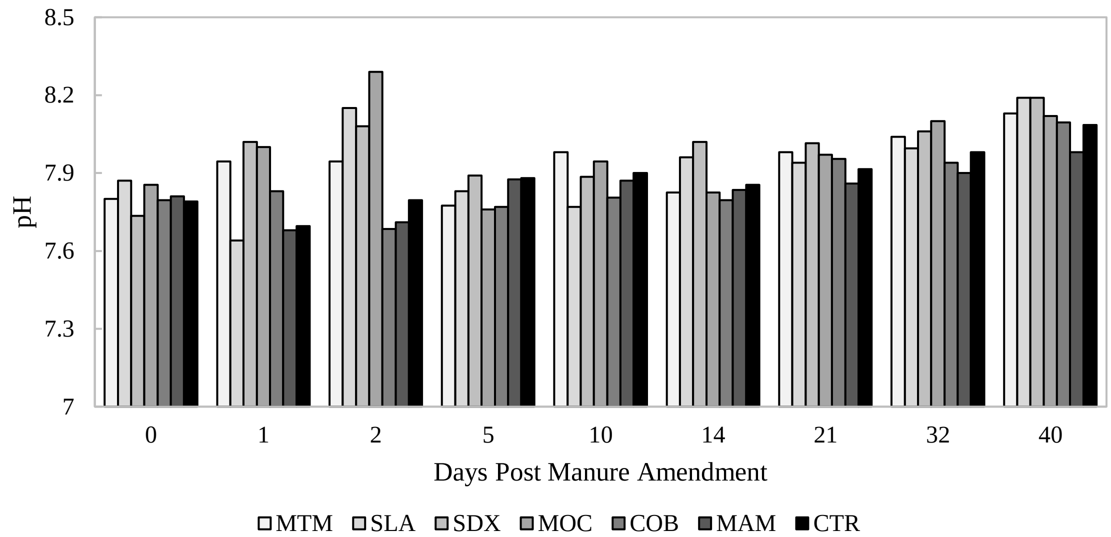


Figure 3.2: Interactive effects of time and manure amendment on pH in the additive experiment.

As can be seen in Table 3.2, for constituents TS, TVS, TSS, and MC, treatments *More Than Manure*, *MOC-7*, *Sludge Away*, and *Sulfi-Doxx* produce the same statistically significant increase from the control. Treatments *Coban 90* and *Manure Magic* do not differ from the Control. In the case of COD, only the *Coban 90* treatment is the same as Control; all other treatments produce statistically larger values.

The relationship between slurry treatment and pH is more complicated. Only *MOC-7* and *Sulfi-Doxx* are statistically different from the control; both are greater. *Coban 90* and *Manure Magic* are less than from *More Than Manure* and *Sludge Away*, though neither set differs from the control. *Sulfi-Doxx* is statistically the same as *More Than Manure* and *MOC-7*.

From Figure 3.1, it can be seen the DO and COD of the slurry appears to be decreasing. The COD trend represents the reduction of microbially biodegraded compounds in the slurry, especially during the first several days of the experiment. Dissolved oxygen levels are extremely low over the course of the experiment, indicating a thoroughly anaerobic environment. TS, TVS, TSS, and TDS all increase over the course of the experiment. As discussed in Section 3.1, this trend is due, at least in part, to the slurry thickening due to evaporation over the course of the experiment. Further investigation is required to determine the effect of slurry amendment on the solids content of the manure.

The interactive effect of pH, as shown in Figure 3.2, indicates a generally increasing trend over time. A peak appears at 2 days post manure amendment for treatments *Sludge Away*, Sufi-Dox, and *MOC-7*. After day 2, pH values remain consistent across all treatments for the duration of the incubation.

3.4 Nutrient Content from Additive Experiment

Constituents analyzed from this sample set are organic nitrogen (ON), ammonium nitrogen (AN), nitrite nitrogen (NN), total nitrogen (TN), phosphorus, potassium, sulfur, calcium, magnesium, sodium, zinc, iron, manganese, copper, boron, electrical conductivity (EC), pH, and dry matter percent (DM). An ANOVA was performed on this data and the results are shown in Table 3.3. Statistically significant results for time effects are shown in Figure 3.3 and interactive effects between time and manure treatment are shown in Figure 3.4.

The effect of manure additive treatment on TN, P, S, Ca, Mg, Zn, Fe, Mg, Cu, B, EC, DM can be seen in Table 3.3. No clear trend is visible from these results. With total nitrogen, for example, the *Coban 90* treatment is the same as the control. *Sludge Away* and *Sulfi-Doxx* are the same as each other, and *More Than Manure* and *Sludge Away* are the same. All other treatments are different. With phosphorus, no treatments are the same as the control, however *Coban 90* and *Manure Magic* are the same and *More Than Manure* and *Sludge Away* are the same.

Every nutrient constituent shown in Figure 3.3 increases over time. Moreover the shape of the curve of each constituent shown increases in much the same way, a sharp increase before day 10, followed by a positive inflection at day 14 and a point slightly below the trendline at day 32. This also indicates evaporation plays a significant role in the positive trend. The below-trendline points at day 32 may be due to a below average temperature week and the above-trendline day 40 points may be due to a above average temperature week.

The only constituent experiencing an interactive effect between time and slurry amendment is potassium. As shown in Figure 3.4, potassium concentration generally increases with time. At one day post manure amendment, *Manure Magic* is significantly lower than the rest of the treatments. At day 32, *MOC-7* is significantly lower than the rest of the treatments as well. In both these cases, the concentration rebounds by the next time point, indicating these measurements may be due to experimental error during the processing of the sample for potassium content. As before, further data analysis is necessary to determine the isolated effect of time on constituent concentration.

Table 3.3: Results of the ANOVA of pit additive and time on chemical characteristics of the manure slurry averaged over eight time points (Additive) and duplicate additive treatments (Time)

	Org N* mg/L	NH3-N mg/L	NO3-N mg/L	Tot N mg/L	P mg/L	K mg/L	S mg/L	Ca mg/L	Mg mg/L
Additive									
Coban 90	2855	2437	2.03	5294 e	5773 d	3575	646 c	1580 c	1576 d
Control	2372	3875	1.49	5249 e	5264 e	3586	637 c	1501 d	1430 e
Manure Magic	2810	2689	1.16	5500 d	5798 d	3510	657 c	1601 c	1582 d
More Than Manure	3130	3216	1.79	6348 b	8796 b	3571	838 ab	2291 ab	2505 b
MOC-7	3530	2665	1.13	6193 c	8407 c	3520	817 b	2226 b	2426 c
Sludge Away	3280	3130	1.28	6414 ab	8783 b	3568	846 a	2312 a	2496 b
Sulfi-Doxx	3403	3038	1.36	6442 a	9212 a	3565	858 a	2360 a	2621 a
Time (days)									
1	2941	2990	1.40	5932	6966	3363	705	1856	1974
2	3147	2794	1.39	5942	7128	3394	719	1857	1992
5	3207	2707	1.56	5915	7293	3446	738	1914	2023
10	2971	2979	1.46	5951	7383	3506	758	1979	2056
14	2994	2889	1.58	5886	7354	3543	752	1964	2074
21	2969	2903	1.64	5873	7540	3629	773	2005	2128
32	3028	2885	1.37	5915	7653	3690	773	2057	2170
40	3178	2766	1.27	5946	8107	3881	838	2218	2310
ANOVA (P > F)									
Additive	0.16	0.16	0.13	**0.01**	**0.01**	0.94	**0.01**	**0.01**	**0.01**
Time	0.55	0.55	0.64	0.39	**0.01**	0.01	**0.01**	**0.01**	**0.01**
Additive x Time	0.83	0.77	0.71	0.8	0.38	**0.01**	0.79	0.84	0.62

Table 3.3 continued:

	Na mg/L	Zn mg/L	Fe mg/L	Mn mg/L	Cu mg/L	B mg/L	EC dSm^{-1}	pH	DM %
Additive									
Coban 90	1018	148 c	201 d	34.6 c	36.1 c	4.92 bc	29.2 b	7.81	4.44 d
Control	1001	141 d	194 d	33.1 c	34.5 d	4.81 c	30.3 a	7.80	4.24 e
Manure Magic	991	148 c	202 d	34.7 c	36.2 c	4.83 c	28.9 b	7.78	4.51 d
More Than Manure	1008	214 b	298 a	53.1 ab	52.1 b	5.24 a	27.3 c	7.76	6.21 b
Moc - 7	972	210 b	275 c	52.7 b	51.0 b	5.05 b	26.5 d	7.76	6.02 c
Sludge Away	995	215 ab	285 b	52.8 b	52.2 ab	5.25 a	27.2 c	7.74	6.01 c
Sulfi-Doxx	1017	221 a	306 a	54.3 a	53.7 a	5.29 a	27.2 c	7.74	6.36 a
Time (days)									
1	940	174	234	42.2	42.3	4.75	28.3	7.72	5.19
2	959	177	239	42.8	42.7	4.86	28.6	7.72	5.13
5	984	181	248	44.0	44.0	4.90	28.4	7.71	5.30
10	992	185	247	45.0	45.0	4.96	28.3	7.72	5.38
14	992	183	250	44.6	44.5	4.99	28.2	7.76	5.34
21	1019	189	256	45.8	45.8	5.18	28.0	7.79	5.44
32	1034	191	262	46.5	46.5	5.29	27.7	7.83	5.60
40	1082	202	277	49.3	50.0	5.50	27.3	7.91	5.82
ANOVA (P > F)									
Additive	0.43	**0.01**	**0.01**	**0.01**	**0.01**	**0.04**	**0.01**	0.27	**0.01**
Time	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Additive xTtime	0.36	0.55	0.33	0.75	0.8	0.22	0.83	0.06	0.14

*Abbreviations: Organic Nitrogen (Org N), Total Nitrogen (Tot N), Electrical Conductivity (EC), Dry Matter (DM)

**Values in the same column followed by different letters are significantly different at the 0.05 probability level based on the LSD test.

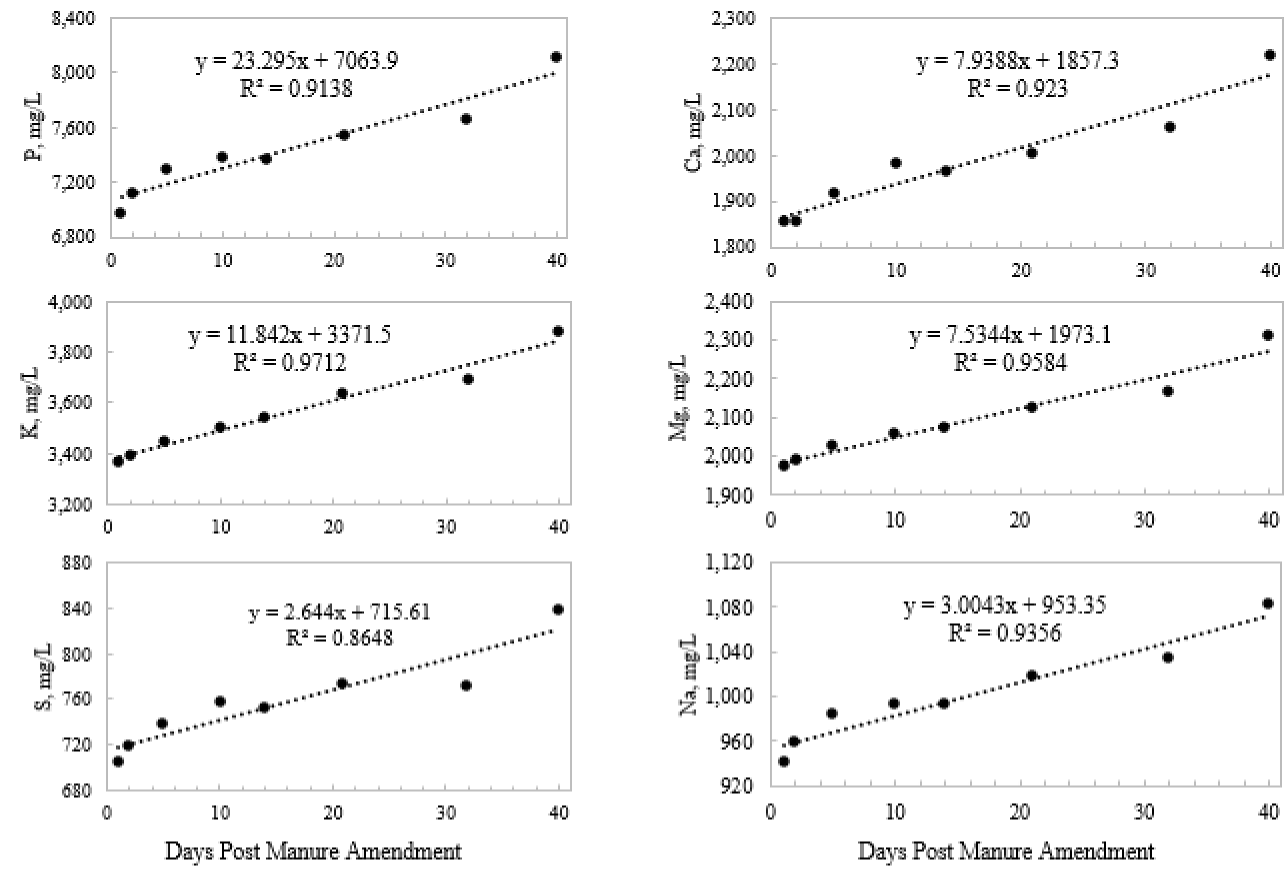


Figure 3.3: Time effects on the nutrient content of the manure in the additives experiment.

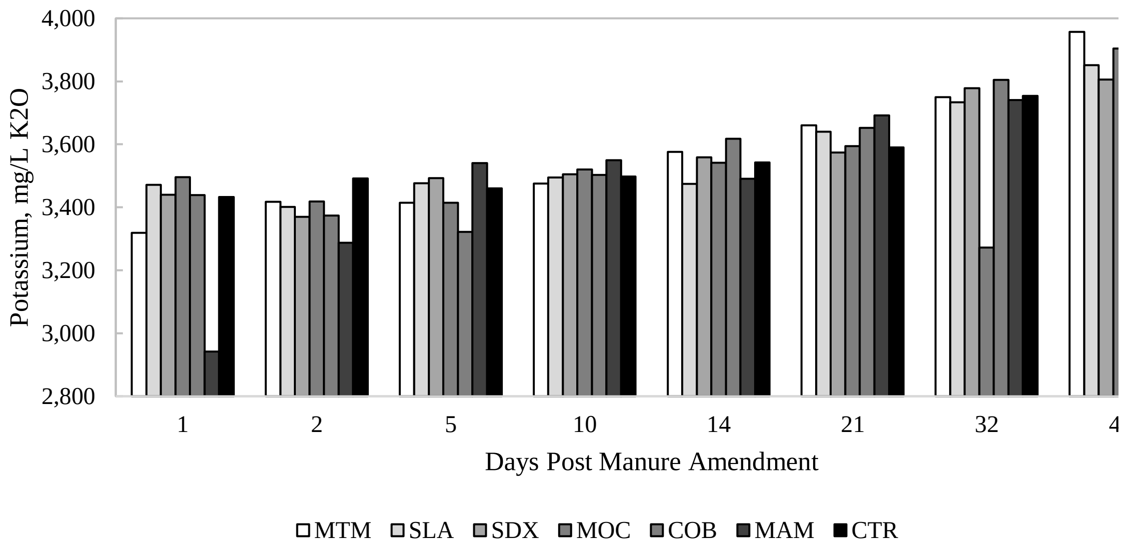


Figure 3.4: Interactive effects of time and manure amendment on potassium concentration.

3.5 Physical Manure Properties from Disinfectant Experiment

The results of an ANOVA for these constituents for the disinfectants experiment is shown in Table 3.4. TS, TVS, and TSS experience statistically significant differences with respect to manure amendment. With TS for example, the *Chlorine Bleach* treatment does not differ from the treatment, however all other treatments do. *Pi-Quat* and *Tek Trol* treatments are the same as each other and *Chlorine Bleach* and *Virkon* are statistically similar as well.

Looking at the statistically significant time effects, presented in Figure 3.5, the trends for DO is negative as with the previous experiment. COD experiences a positive trend, which is opposite that experienced in the previous experiment. TS and TSS experience a positive trend. Whether or not the decrease in moisture content is the cause of the increase in TS and TSS requires further data analysis.

TVS, TSS, pH and MC experience interactive effects between time and manure amendment, as shown in Figure 3.6. With TVS, *Pi-Quat* and *Tek Trol* treatments are significantly higher than the other treatments. With TSS the trend is negative until day 21 at which time the trend becomes positive. The MC generally decreases with time however the *Pi-Quat* treatment is consistently the lowest of the treatments.

Table 3.4: Results of the ANOVA of disinfectant and time on physical characteristics of the manure slurry averaged over eight time points (Disinfectant) and duplicate additive treatments (Time)

	pH	DO* mg/L	COD mg/L	TS mg/L	TVS mg/L	TSS mg/L	TDS mg/L	MC %
Disinfectant								
Chlorine Bleach	7.77 a	0.06	88540	80910 bc	51410 c	59570 cd	25560 bc	91.9 a
Control	7.84 a	0.06	85460	81690 b	52470 b	61980 bc	26800 ab	91.7 b
Pi-Quat	7.47 b	0.06	89290	83550 a	54690 a	68660 a	25350 bc	91.6 c
Tek Trol	7.58 b	0.07	86200	84430 a	55310 a	65780 ab	28080 a	91.4 c
Virkon	7.80 a	0.01	83250	79900 c	50510 c	55880 b	24440 c	91.9 a
Time (days)								
1	7.52	0.08	80740	82425	53584	57795	31337	
2	7.86	0.05	81840	80357	52378	62055	28031	91.9
5	7.62	0.05	95740	81200	52873	64680	30304	91.8
10	7.74	0.07	88040	82185	53285	58680	21624	91.9
14	7.65	0.07	79040	82375	53408	60870	22371	91.8
21	7.61	0.07	92520	80688	51924	60690	21360	91.6
32	7.72	0.06	86600	83719	52973	65240	25181	91.6
40	7.72	0.04	94120	83829	52589	68975	28164	91.3
ANOVA (P>F)								
Additive	0.01	0.23	0.28	**0.03**	**0.01**	**0.01**	0.01	0.02
Time	0.04	**0.01**	**0.01**	**0.01**	0.19	**0.02**	0.01	0.01
A x T	**0.01**	0.27	0.23	0.39	0.09	0.10	**0.01**	**0.01**

*Abbreviations: Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Solids (TS), Total Volatile Solids (TVS), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), High Temperature (HT), Low Temperature (LT).

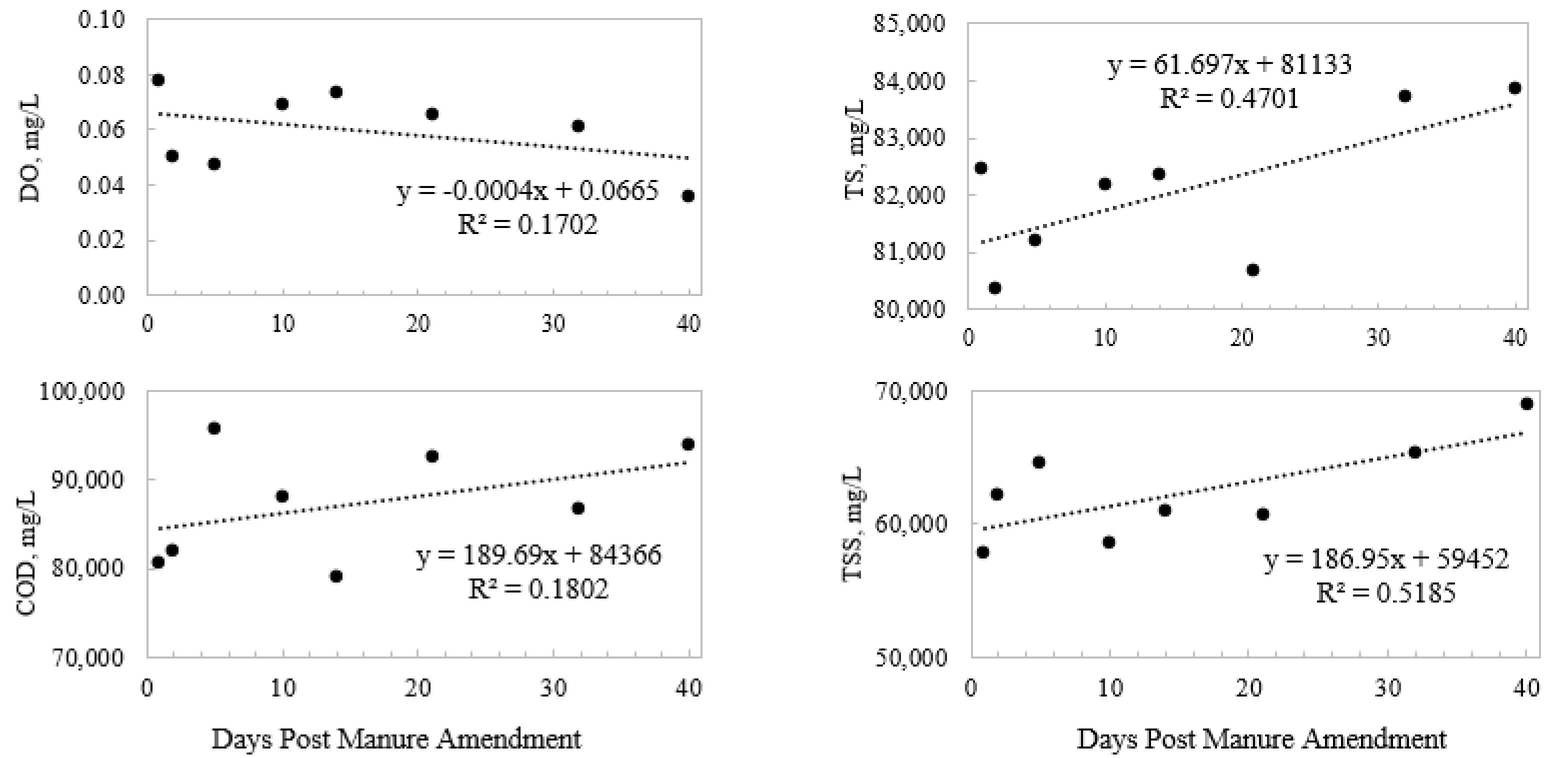


Figure 3.5: Time effects of the physical properties of the manure in the disinfectants experiment.

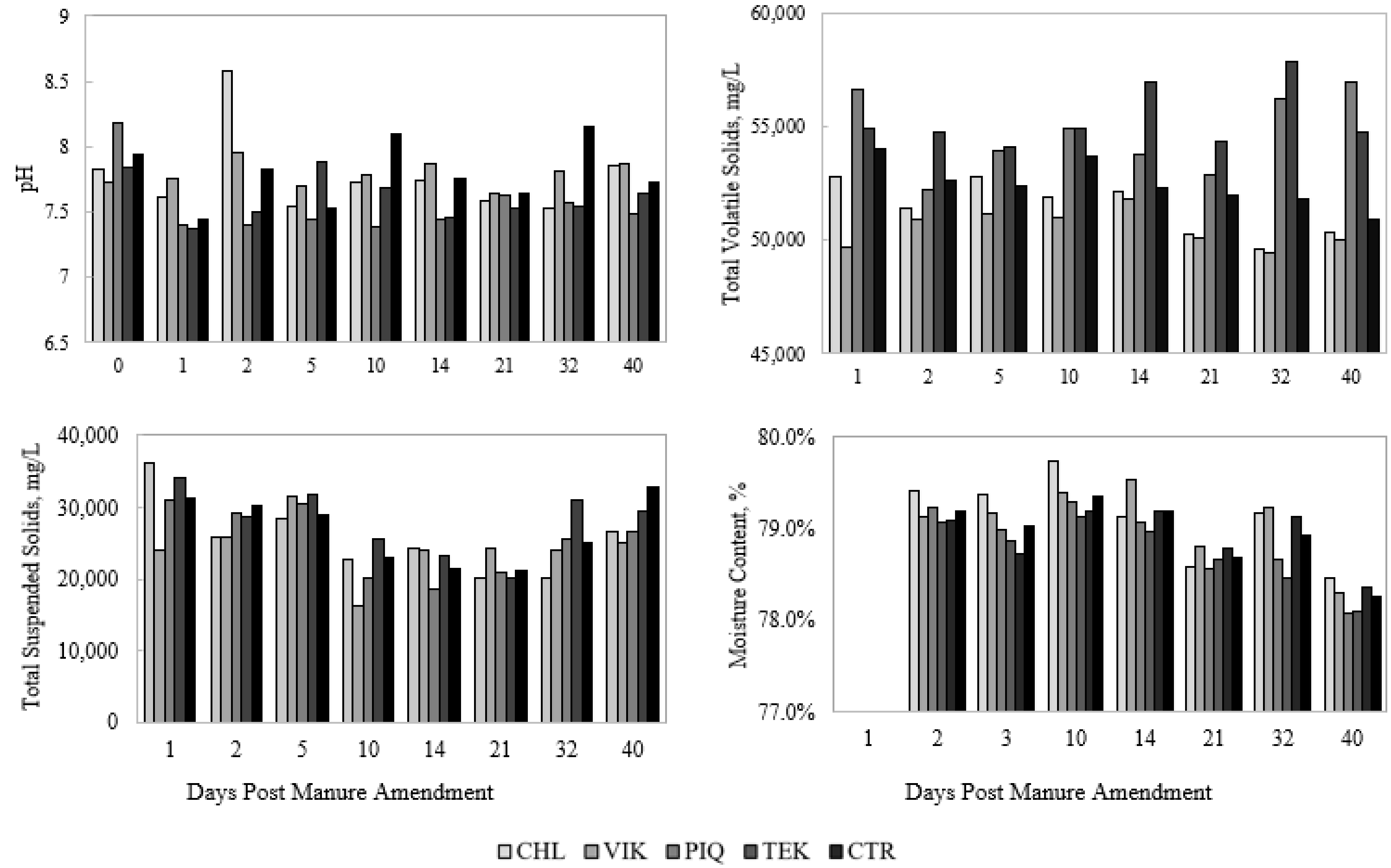


Figure 3.6: Interactive effects of pH, TVS, TSS, and MC in the physical properties of the disinfectant experiment slurry.

3.6 Nutrient Content from Disinfectant Experiment

The ANOVA for the nutrient composition in the disinfectant experiment is given in Table 3.5. Three constituents (nitrate nitrogen and sodium) experience statistically significant effects with additive treatment. For nitrate nitrogen, *Pi-Quat* does not differ from the control. *Pi-Quat* and *Tek Trol* are statistically the same, as are *Chlorine Bleach* and *Virkon*. For sodium, *Pi-Quat* and *Virkon* do not differ from the control. *Chlorine Bleach* and *Tek Trol* differ from the control and from each other.

P, K, Ca, Mg, Na, Zn, Fe, Mn, Cu, and B show statistically significant effects with time, as seen in Figure 3.7. Each of these constituents demonstrates roughly the same increasing trend. This is also the same trend seen by the nutrient constituents in the additive experiment. Once again, this linearly increasing trend is believed to be caused, at least in part by a slight thickening of the manure slurry due to evaporation. Further analysis is needed to elicit the effect of time on the nutrient concentration.

Total nitrogen, sulfur, electrical conductivity, pH and dry matter percent demonstrate statistically significant interactive effects between time and manure treatment, as seen in Figure 3.8. With total nitrogen *Chlorine*, *Virkon*, and control treatments experience an increasing trend. *Pi-Quat* and *Tek Trol* demonstrate an overall decrease in concentration, however both experience increases during the middle of the incubation. With the total suspended solids, all treatments demonstrate an initial decrease before increasing to near their initial values. At many sampling points there is a high variability between treatments. With sulfur, all treatments experience an increasing trend, however *Virkon* and control treatments experience a significantly larger increase than other treatments. Electrical conductivity experiences a slight downward trend, while the variability between treatments increases over the course of the incubation.

Table 3.5: Effects of disinfectant and time on chemical characteristics of the manure slurry averaged over eight time points (Disinfectant) and duplicate additive treatments (Time)

	Org N* mg/L	NH3-N mg/L	NO3-N mg/L	Tot N mg/L	P mg/L	K mg/L	S mg/L	Ca mg/L	Mg mg/L
Disinfectant									
Chlorine Bleach	3,736	3,536	1.31 c	7,273	9,780	3,870	830	2,603	2,500
Control	3,932	3,386	3.38 a	7,321	9,864	3,863	841	2,609	2,428
Pi-Quat	3,681	3,443	2.73 ab	7,127	9,645	3,843	807	2,562	2,442
Tek Trol	3,474	3,593	2.11 bc	7,069	9,719	3,926	850	2,573	2,491
Virkon	4,266	3,035	1.10 c	7,303	9,853	3,846	837	2,600	2,484
Time (days)									
1	3,651	3,497	1.93	7,150	9,356	3,693	796	2,463	2,392
2	3,838	3,384	1.35	7,224	9,284	3,687	788	2,456	2,370
5	3,971	3,294	2.31	7,267	9,352	3,714	807	2,451	2,344
10	3,806	3,295	1.76	7,103	9,470	3,763	804	2,479	2,391
14	3,568	3,554	2.11	7,124	9,595	3,796	809	2,554	2,470
21	3,920	3,322	2.09	7,244	9,888	3,902	844	2,658	2,499
32	3,829	3,478	3.28	7,312	10,306	4,094	867	2,739	2,561
40	3,959	3,364	2.17	7,326	10,925	4,309	949	2,917	2,727
ANOVA (P > F)									
Additive	0.59	0.77	**0.02**	0.19	0.70	0.17	0.13	0.86	0.56
Time	0.84	0.98	0.31	0.01	**0.01**	**0.01**	0.01	**0.01**	**0.01**
Additive x time	0.72	0.83	0.84	**0.01**	0.25	0.50	**0.01**	0.15	0.32

Table 3.5 continued:

	Na mg/L	Zn mg/L	Fe mg/L	Mn mg/L	Cu mg/L	B mg/L	EC dSm^{-1}	pH	DM %
Additive									
Chlorine Bleach	1,142 a	229	281	59.4	50.4	3.94	26.5 a	7.61 b	7.76
Control	1,011 c	228	286	59.6	50.5	4.26	26.3 a	7.61 b	7.89
Pi-Quat	1,011 c	226	287	58.2	49.4	3.98	25.7 b	7.60 b	8.01
Tek Trol	1,070 b	227	289	58.6	49.5	4.03	25.6 b	7.71 a	8.12
Virkon	1,011 c	230	279	60.1	50.9	4.16	26.5 a	7.58 b	7.80
Time (days)									
1	1,004	217.82	274	56.56	47.84	3.98	26.41	7.63	7.68
2	999	218.04	276	56.22	47.54	3.65	26.33	7.61	7.62
5	1,002	218.56	269	56.84	48.37	3.96	26.36	7.65	7.77
10	1,019	220.70	274	57.19	48.30	3.95	26.42	7.65	7.73
14	1,026	223.63	282	58.12	49.15	3.85	26.21	7.59	7.80
21	1,062	232.29	285	60.11	51.17	4.06	25.77	7.55	8.03
32	1,109	238.04	299	62.36	52.70	4.58	25.87	7.62	8.16
40	1,169	256.91	317	66.11	56.22	4.53	25.59	7.65	8.55
ANOVA (P > F)									
Additive	**0.01**	0.80	0.44	0.31	0.28	0.30	0.01	0.02	0.07
Time	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	0.01	0.01	0.01
Additive x time	0.32	0.09	0.27	0.24	0.14	0.76	**0.01**	**0.03**	**0.01**

*Abbreviations: Organic Nitrogen (Org N), Ammonium Nitrogen (NH3-N), Nitrate Nitrogen (NO3-N), Total Nitrogen (Tot N), Electrical Conductivity (EC), Dry Matter (DM)

**Values in the same column followed by different letters are significantly different at the 0.05 probability level based on the LSD test.

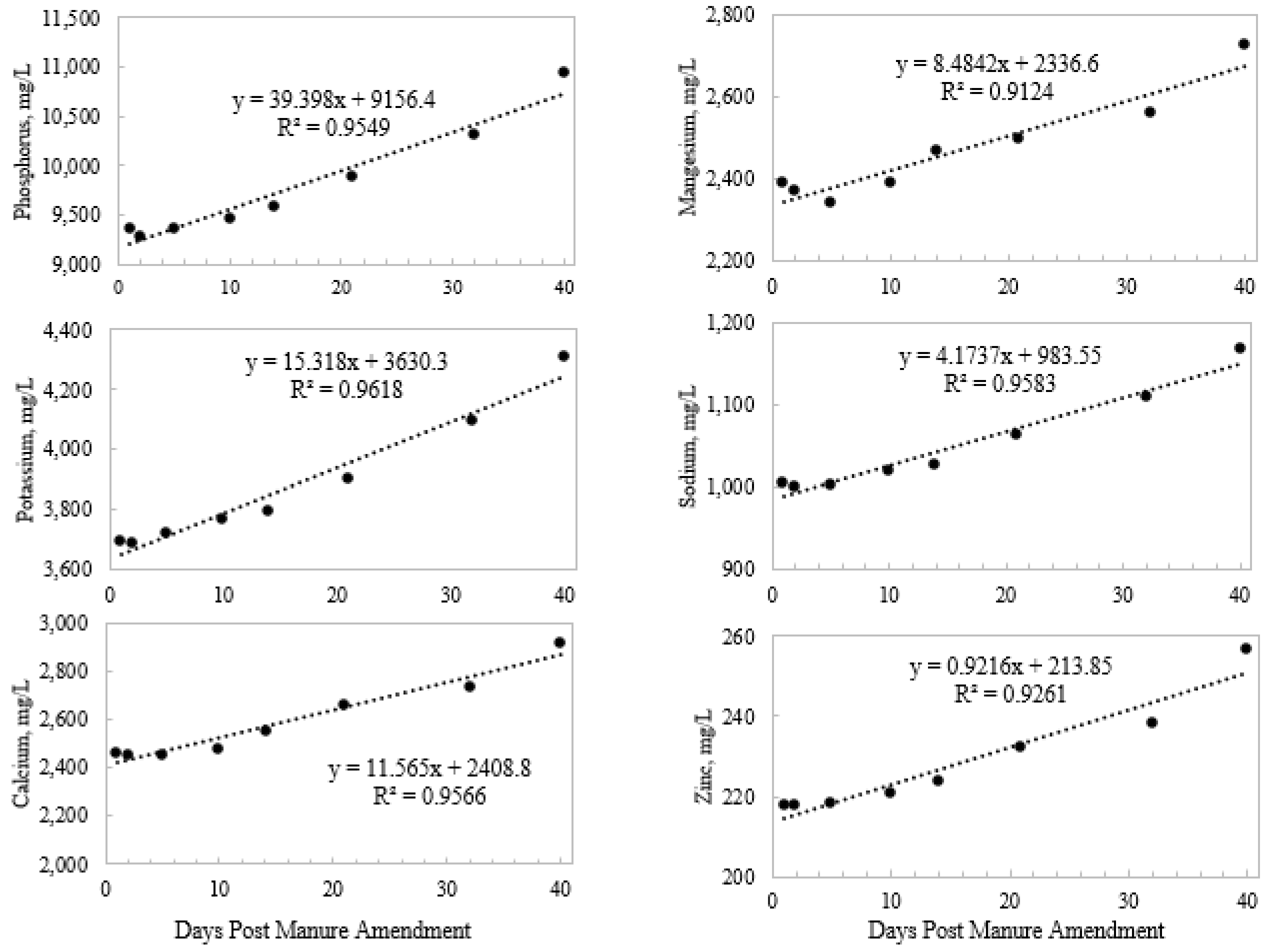


Figure 3.7: Time effects on the nutrient content of the manure in the disinfectants experiment.

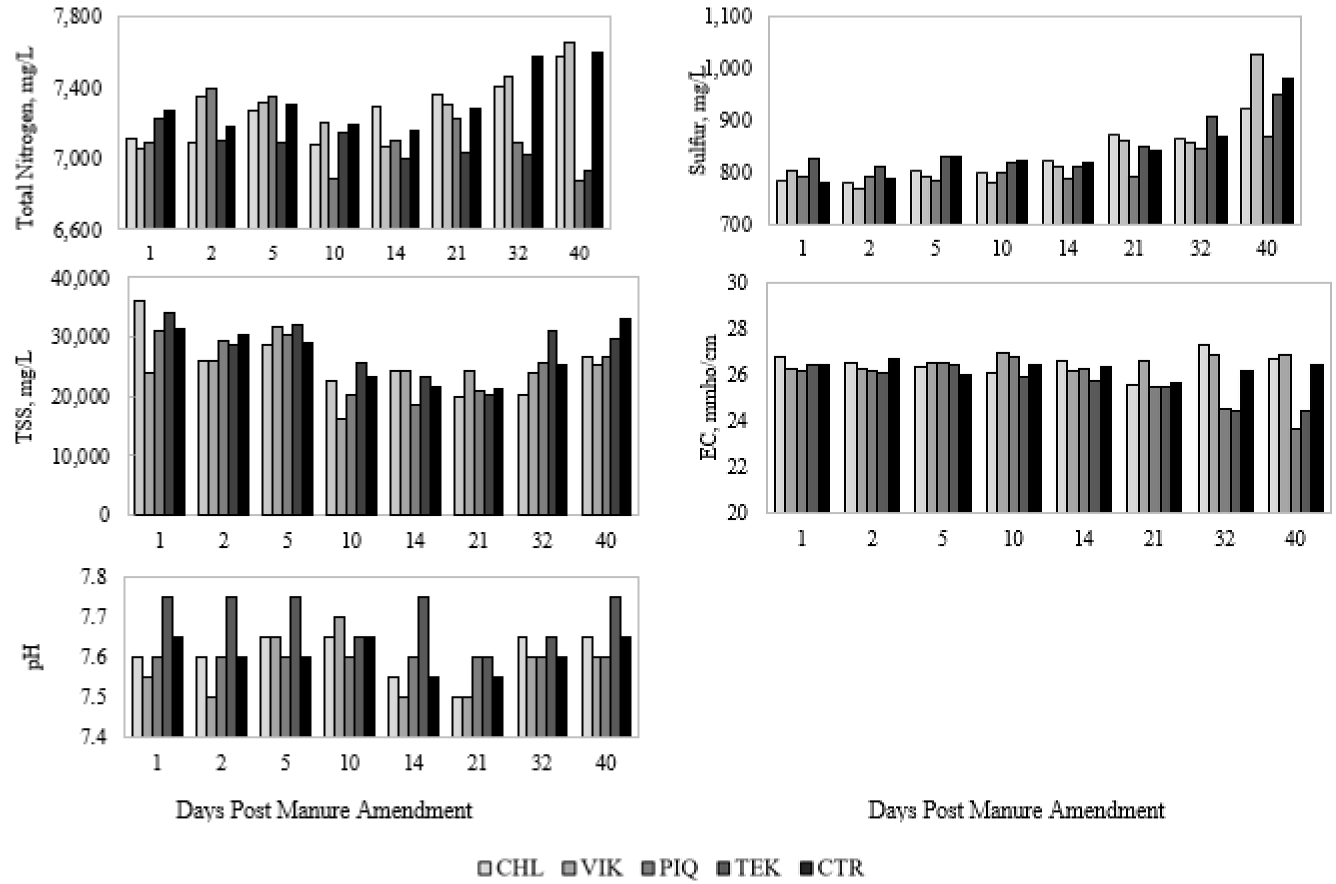
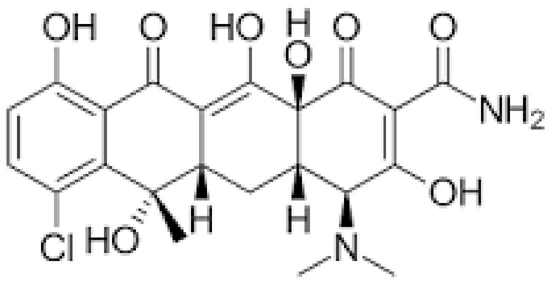


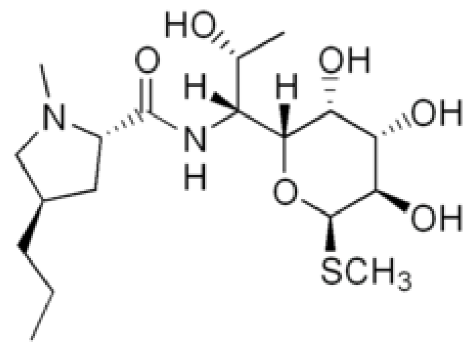
Figure 3.8: Interactive effects of total nitrogen, sulfur, TSS, electrical conductivity, and pH in the disinfectants experiment.

3.7 Antibiotics Data from both Experiments

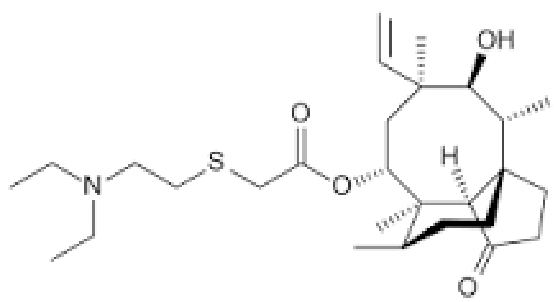
As shown in Figure 3, three antibiotics were detected in the manure slurry for the additives experiment, chlortetracycline, lincomycin, and tiamulin. Structures and chemical properties of each are provided in Figure 3.9 and Table 3.6. It was expected that the antibiotics concentrations would demonstrate an exponential decrease, such as would be expected for first order decay, however this behavior was not observed. In contrast, many concentrations appear to increase over the course of the experiment.



Chlortetracycline



Lincomycin



Tiamulin

Figure 3.9: Chemical structures of the detected antibiotics.

Table 3.6: Properties of the detected antibiotics.

Name	Chlortetracycline[1]	Lincomycin[2]	Tiamulin[3]
Formula	$C_{22}H_{23}ClN_2O_8$	$C_{18}H_{34}N_2O_6S$	$C_{28}H_{47}NO_4S$
Molar Mass (g/mol)	478.882	406.538	493.742
pKa Range	3.58 – 7.97	3.24 – 8.41	9.51
Water Solubility (mg/mL)	0.288	3.02	Not soluble
Log K_d	NA	0.56	NA
Log K_{ow}	-0.68	0.20	4.75

[1]Chlortetracycline, n.d. [2]Lincomycin, n.d. [3]Tiamulin, n.d.

There was also large variability in chlortetracycline concentrations between treatments and sometimes between treatment replicate as well. Values ranged from 1,000 ng/g to 25,000 ng/g. For example, while replicate samples for the control reactors were roughly the same, replicates for the Coban treatment were different by 2 to 3 times. Meanwhile

MOC-7, *More Than Manure*, *Sulfi-Doxx*, and *Sludge Away* treatments contain concentrations as much as 3 time greater than those found for the *Manure Magic* treatment or the control.

Lincomycin was measured at concentrations 1 to 2 orders of magnitude less than those measured for chlortetracycline. Concentrations range between approximately 25 ng/g and 1000 ng/g. In general, concentrations vary to a greater extent for lincomycin than for chlortetracycline. Both replicates of the *Coban 90* treatment as well as the first replicate for *More Than Manure* demonstrate unusually wide variability in concentration. The control, *Sludge Away*, and *Sulfi-Doxx* all demonstrate more consistency between replicates. Once again, no discernable trend was observable in the data. Some concentration time series appear to increase, some remain approximately the same, but no series demonstrates what could be characterized as a linear or exponential decrease.

Tiamulin was measured at concentrations the same order of magnitude as was measured for lincomycin. Once again there is a large variability in measured concentrations. Values range from approximately 50 ng/g to 950 ng/g. Almost all concentration time series exhibit large differences between the smallest and greatest values. This is especially true for both replicates of *MOC-7* and for the first replicate of *More Than Manure*. The notable exception to this is *Manure Magic* which does not have any large outstanding concentrations. In general, tiamulin concentrations between treatments were more consistent than for chlortetracycline or lincomycin.

Chlortetracycline demonstrated statistically significant effects, displayed in Table 6, for time and for treatment. Lincomycin demonstrated a statistically significant time effect. Tiamulin demonstrated a statistically significant time effect as well as a significant interactive effect between treatment and time. For chlortetracycline, treatments *MOC-7*, *More Than Manure*, *Sludge Away*, and *Sulfi-Doxx* all differ from the control, being greater by roughly a factor of two across all time points.

For lincomycin, only the *Coban 90* treatment was significantly greater than the control. Because the reported antibiotics concentrations do not follow a physically explainable trend, such as a zero or first order decay, it is not apparent what the cause of these results are.

For chlortetracycline, treatments *MOC-7*, *More Than Manure*, *Sulfi-Doxx*, and *Sludge Away* each exhibit means that are less than the control at the 95% confidence interval. This could indicate that these treatments inhibit the degradation of chlortetracycline. Analysis of the normalized data is needed to know for sure.

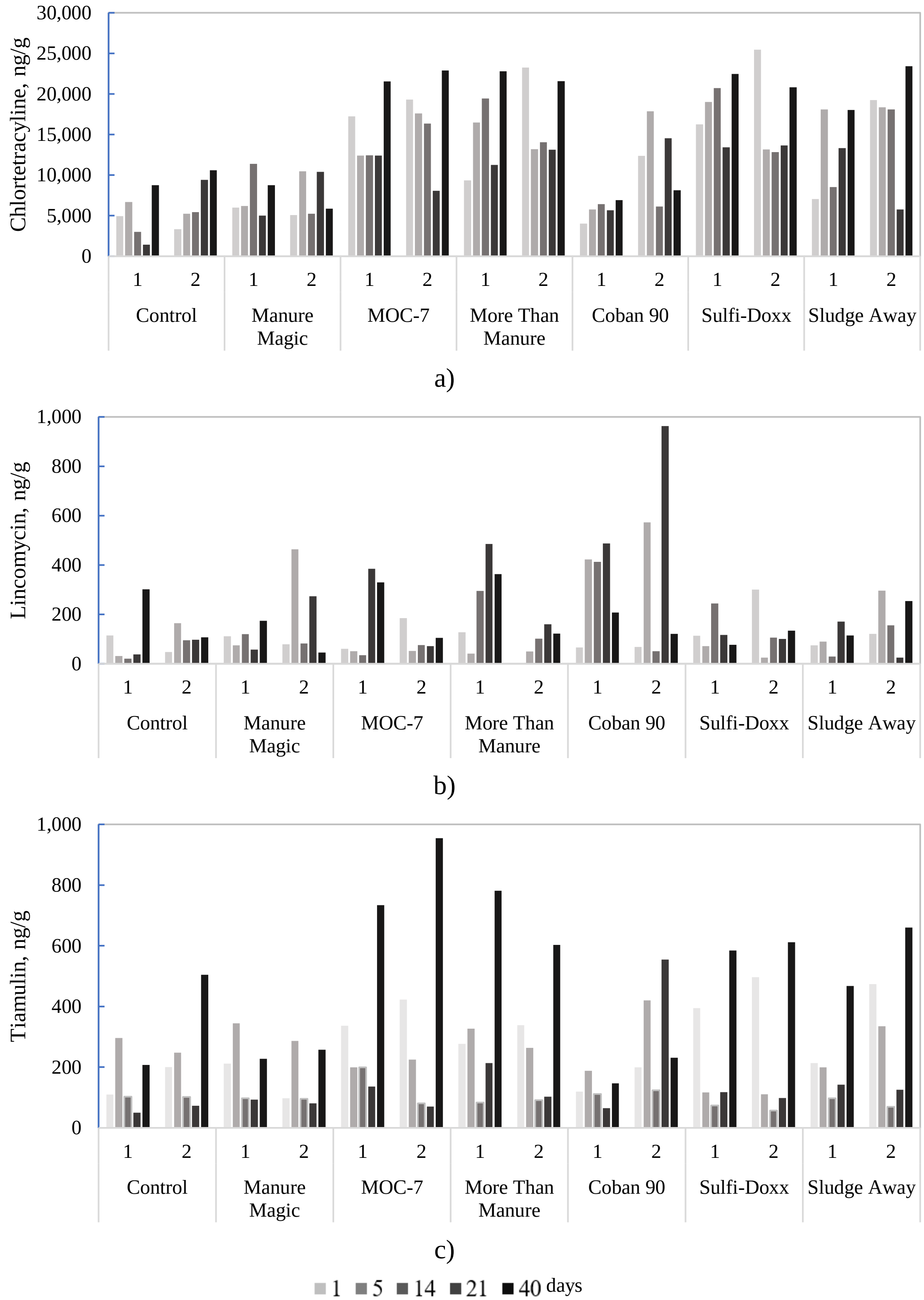


Figure 3.10: Antibiotics levels for the additives experiment. a) Chlortetracycline, b) Lincomycin, and c) Tiamulin levels reported in ng antibiotic per g manure dry weight for 5 time points post manure amendment.

The same three antibiotics were detected in the manure slurry during the disinfectants experiment. The results for the ANOVA on each of these antibiotics is presented in Table 3.7. It was once again expected that the concentrations of antibiotics would decrease exponentially over the course of the experiment. The data does not, however, follow this expected trend. Instead, for many antibiotics, the concentrations increases, or follow a trend of a decreasing followed by increasing concentrations between replicates and between time points. Moreover, there is a large variability in the antibiotics concentrations. Both lincomycin and tiamulin demonstrate greater than an order of magnitude in in variability in reported antibiotics concentrations. Because of this variability and lack of consistent identifiable trends, values for both replicate reactors are provided in Figure 3.10.

For chlortetracycline, the antibiotics levels vary between approximately 1,800 and 188,000 ng/g. Other than one obvious outlier, this dataset is the most consistent of the three. The general trend of this data is sharp decrease between days 1 and 5, followed by a more gradual increase in days 14, 21, and 40. Notable exceptions to this are the first replicate of *Pi-Quat* and the second replicate of *Tek Trol*. Lincomycin concentrations do not display as consistent of a trend as the chlortetracycline concentrations. Concentrations range between 51 and 2100 ng/g. Lincomycin concentrations are less variable after exposure to *Chlorine* and *Virkon*, while control and the first time series for the *Pi-Quat* treatment demonstrate high variability.

The tiamulin concentrations also do not demonstrate any consistent trends between treatments and vary between 9 and 440 ng/g. Concentrations reported for *Tek Trol* are at the low end of those measured for the additives, varying between 9 and 90 ng/g. Values for the *Pi-Quat* treatment are at the high end, varying between 160 and 440 ng/g. *Chlorine Bleach* and *Virkon* treatments demonstrate a sharp decrease in concentration followed by an increase. The *Tek Trol* treatment demonstrated a trend of increasing concentrations followed by decreasing concentration. The *Pi-Quat* and control treatments both demonstrate increasing trends.

The only statistically significant trends observed in the antibiotics concentrations are for tiamulin, which experiences effects for both time and treatment. The overall trend observed for tiamulin is generally increasing but exhibits a decrease through days 1, 5, and 14 before increasing more sharply in days 21 and 40. The treatment effects indicate that both the *Chlorine Bleach* treatment and control behaved the same as the *Virkon* treatment, though they did not behave the same as each other. The average percent recovery for the surrogate compound oleandomycin was 105% with a standard deviation of 30.7% for the additives experiment and 130%, with a standard deviation of 69.6% for the disinfectants experiment. This indicates good recovery of antibiotics from the manure, but with significant variability in recovery between samples. Once again, further analysis based on the normalization of the concentrations by day 40 values will be done before final conclusions are made.

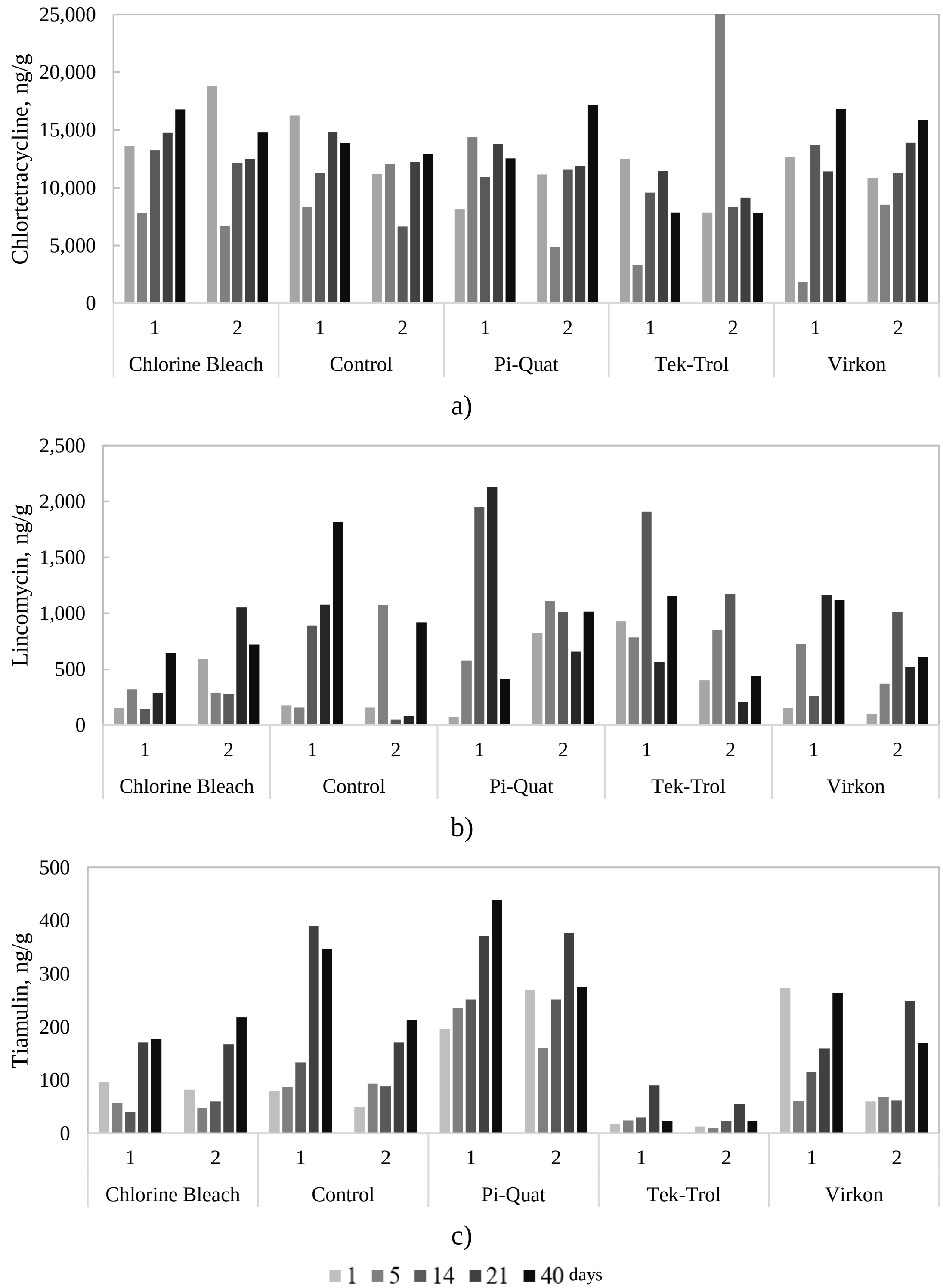


Figure 3.11: Antibiotics levels for the disinfectant experiment. a) Chlortetracycline, b) Lincomycin, and c) Tiamulin levels reported in ng antibiotic per g manure dry weight for 5 time points post manure amendment.

Table 3.7: ANOVA results for the antibiotics in the additives experiment.

	Chlortetracycline ng/g	Lincomycin ng/g	Tiamulin ng/g
Additive			
Coban	8,784 b	337 a	216
Control	5,886 b	102 b	189
Manure Magic	7,437 b	148 b	179
MOC-7	16,027 a	135 b	336
More Than Manure	16,454 a	193 b	308
Sludge Away	14,986 a	133 b	278
Sulfi-Doxx	17,777 a	129 b	266
Time (days)			
1	12,351	118	278
5	12,894	172	254
14	11,432	130	99
21	9,819	245	137
40	15,898	175	498
ANOVA (P>F)			
Additive	**0.003**	**0.032**	0.221
Time	**0.011**	0.136	**6.0E-12**
A x T	0.726	0.108	**8.9E-05**

Table 3.8: ANOVA results for the antibiotics in the disinfectants experiment.

	Chlortetracycline ng/g	Lincomycin ng/g	Tiamulin ng/g
Disinfectant			
Chlorine Bleach	13,120	449	112c
Control	11,971	641	165b
Pi-Quat	11,643	976	283a
Tek Trol	26,624	842	31d
Virkon	11,686	604	148bc
Time (days)			
1	12,312	358	114
5	25,625	627	84
14	10,872	868	106
21	12,592	775	220
40	13,643	885	215
ANOVA (P>F)			
Disinfectant	0.637	0.250	**0.0054**
Time	0.728	0.115	**1.4E-05**
D x T	0.528	0.448	0.438

3.8 Physical Manure Properties from Additives Experiment, Normalized

The results of the ANOVA and LSD test for the normalized physical properties of the slurry for the additives experiment is shown in Table 3.8. As can be seen, DO and TSS demonstrate statistically significant differences with respect to treatment means. For DO, all treatments are similar except for *Sludge Away*, which has a higher mean the others. For TSS, the *Coban 90* treatment had a statistically greater mean when compared to all other treatments. Figure 3.11 shows the statistically significant results for DO and TSS. With TSS, it appears one high concentration measured on day 21 may be responsible for the larger slope of the *Sludge Away* series, so this trend must be examined with care.

Time still has a strong effect on the normalized data. All constituents except DO demonstrate statistically significant time effects well above the 95% confidence level. Unlike the original data, no interactive effects appear for these data.

Table 3.9: Isolated effect of time and treatment on physical properties of the manure slurry in the additives experiment.

	pH	DO mg/L	COD mg/L	TS mg/L	TVS mg/L	TSS mg/L	TDS mg/L
Additive (Mean)							
Coban 90	0.976	1.209 b	0.955	0.883	0.891	1.074 a	0.988
Control	0.982	1.294 b	0.993	0.851	0.864	0.892 b	0.987
Manure Magic	0.985	1.328 b	1.063	0.925	0.955	0.860 b	0.930
More Than Manure	0.978	1.405 b	0.975	0.880	0.833	0.902 b	0.851
MOC - 7	0.971	1.100 b	0.958	0.914	0.920	0.848 b	0.935
Sludge Away	0.979	2.172 a	0.975	0.862	0.885	0.854 b	0.901
Sulfi-Doxx	0.969	1.250 b	1.040	0.873	0.893	0.831 b	0.975
Additive (Slope)							
Coban 90	6.82E-04	7.88E-03	-8.13E-03	4.42E-03	4.12E-03	7.70E-03	8.12E-03
Control	8.44E-04	-1.51E-02	-3.77E-03	2.74E-03	1.12E-03	6.45E-04	5.31E-03
Manure Magic	1.03E-04	-2.49E-02	1.46E-04	4.57E-03	3.49E-03	3.40E-03	1.43E-02
More Than Manure	5.43E-04	-9.10E-03	4.94E-04	9.30E-03	1.46E-02	6.25E-03	1.51E-02
MOC - 7	8.54E-04	-1.11E-02	-2.57E-03	7.88E-03	7.71E-03	1.29E-02	1.33E-02
Sludge Away	2.11E-04	-2.18E-02	-8.52E-03	9.88E-03	8.77E-03	3.96E-03	1.41E-02
Sulfi-Doxx	5.43E-04	-6.65E-02	-4.67E-03	7.43E-03	6.86E-03	5.17E-03	1.23E-02
Days after dosing							
1	0.965	1.917	1.098	0.743	0.765	0.855	0.860
2	0.980	1.600	1.144	0.692	0.711	0.743	0.700
5	0.965	1.301	0.917	0.904	0.945	0.861	0.853
10	0.971	1.497	0.920	0.913	0.940	0.871	0.953
14	0.971	1.637	0.963	0.873	0.874	0.878	
21	0.980	1.036	0.943	0.944	0.959	1.017	1.065
32	0.986	1.164	0.969	0.962	0.965	0.943	1.136
40	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ANOVA (P > F)							
Additive (mean)	0.521	**0.020**	0.521	0.687	0.462	**0.006**	0.709
Additive (slope)	0.643	0.357	0.203	0.255	0.058	0.872	0.545
Time	**8.71E-10**	0.070	**6.40E-07**	**7.01E-08**	**7.36E-05**	**4.94E-03**	**1.28E-06**
Additive (mean) x time	0.006	0.855	0.239	0.591	0.973	0.546	0.880

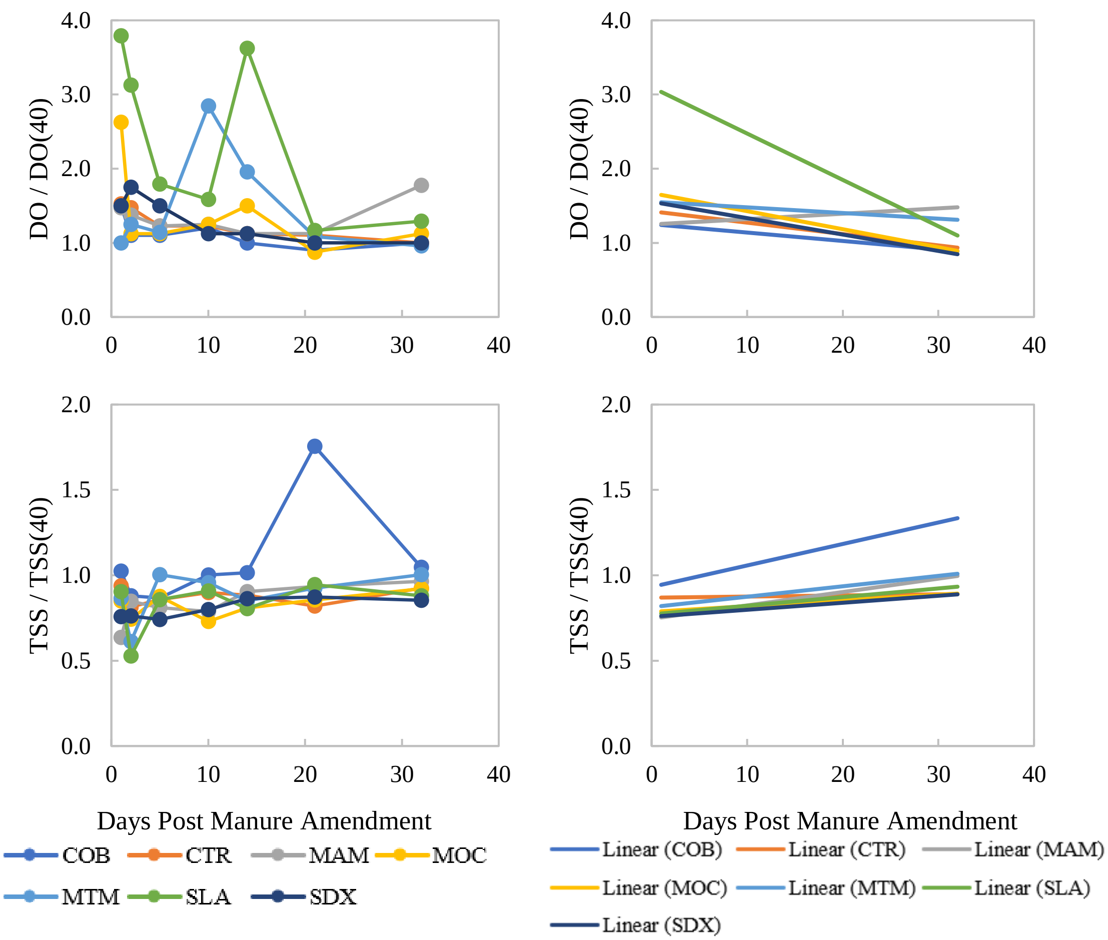


Figure 3.12: Statistically significant trends of the physical properties of the manure slurry in the additives experiment. Normalized data series are given in the left column and linear regressions are given in the right.

3.9 Nutrient Content from Additive Experiment, Normalized

The only treatment effect from this portion of data is for EC relative to slope. The control and *Coban 90* treatments are statistically greater than the other treatments. This result is shown in Table 3.9 and Figure 3.12, where it can be seen that all treatments are clustered together quite closely, but Control and *Coban 90* have a significantly more negative slope than the others. Many constituents (P, K, S, Ca, Mg, Na, Zn, Fe, Mn, Cu, B, EC, pH, DM) still experience a time effect, as is expected. Once again, no interactive effects were observed for this dataset.

Table 3.10: Isolated effect of time and treatment on nutrient content of the manure slurry in the additives experiment.

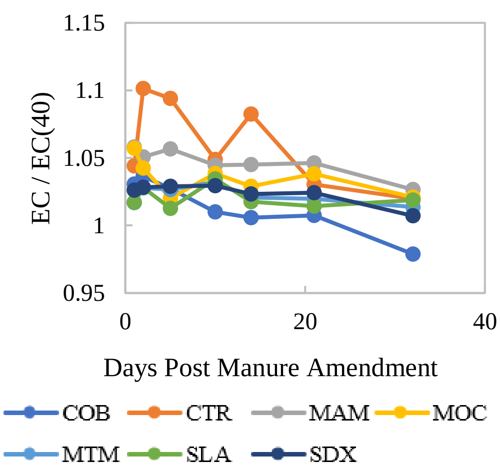
	Org N mg/L	NH3-N mg/L	NO3-N mg/L	Tot N mg/L	P mg/L	K mg/L	S mg/L
Additive (Mean)							
Coban 90	0.939	1.037	1.200	0.990	0.894	0.915	0.858
Control	1.037	0.965	0.867	0.985	0.868	0.914	0.869
Manure Magic	1.016	0.960	0.950	0.988	0.902	0.902	0.899
More Than Manure	0.930	1.090	1.313	0.999	0.904	0.903	0.901
MOC - 7	0.876	1.233	1.565	1.011	0.944	0.919	0.949
Sludge Away	1.033	0.990	0.972	1.008	0.956	0.938	0.927
Sulfi-Doxx	0.932	1.067	1.281	0.990	0.939	0.927	0.928
Additive (Slope)							
Coban 90	-9.71E-03	8.41E-03	-1.67E-03	-7.66E-04	4.28E-03	4.95E-03	3.92E-03
Control	1.71E-03	-3.39E-03	-1.55E-02	-9.61E-04	3.01E-03	2.38E-03	3.62E-03
Manure Magic	-5.79E-03	6.33E-03	3.15E-03	3.57E-04	-4.93E-04	-8.80E-04	-7.54E-04
More Than Manure	2.39E-03	-3.40E-03	-3.39E-03	-7.02E-05	3.61E-03	3.32E-03	3.49E-03
MOC - 7	6.71E-03	-9.30E-03	1.18E-02	1.50E-05	1.61E-03	3.64E-03	2.33E-03
Sludge Away	-2.29E-03	2.19E-03	1.71E-03	-2.05E-04	2.97E-03	2.89E-03	2.70E-03
Sulfi-Doxx	5.18E-04	-8.32E-04	7.01E-03	4.23E-05	1.96E-03	2.58E-03	2.01E-03
Days after dosing							
1	0.935	1.100	1.119	0.998	0.856	0.867	0.841
2	0.990	1.023	1.127	1.000	0.879	0.875	0.859
5	1.012	0.999	1.237	0.995	0.899	0.888	0.882
10	0.943	1.091	1.175	1.001	0.910	0.904	0.908
14	0.953	1.066	1.247	0.990	0.908	0.913	0.898
21	0.944	1.068	1.311	0.988	0.928	0.936	0.923
32	0.950	1.042	1.097	0.994	0.944	0.951	0.925
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ANOVA (P > F)							
Additive (mean)	0.554	0.209	0.185	0.414	0.342	0.834	0.558
Additive (slope)	0.075	0.079	0.671	0.704	0.522	0.411	0.467
Time	0.695	0.520	0.628	0.379	**3.55E-12**	**9.46E-12**	**2.76E-11**
Additive (mean) x time	0.744	0.774	0.714	0.786	0.305	0.413	0.710

Table 3.10 continued:

	Ca mg/L	Mg mg/L	Na mg/L	Zn mg/L	Fe mg/L	Mn mg/L	Cu mg/L
Additive (Mean)							
Coban 90	0.857	0.875	0.933	0.882	0.874	0.890	0.876
Control	0.847	0.869	0.908	0.885	0.871	0.864	0.852
Manure Magic	0.895	0.902	0.895	0.902	0.883	0.909	0.901
MOC - 7	0.929	0.919	0.941	0.957	0.949	0.940	0.940
More Than Manure	0.905	0.898	0.902	0.907	0.905	0.904	0.898
Sludge Away	0.927	0.937	0.949	0.951	0.947	0.957	0.938
Sulfi-Doxx	0.889	0.918	0.952	0.944	0.934	0.925	0.911
Additive (Slope)							
Coban 90	5.29E-03	4.78E-03	4.46E-03	4.54E-03	4.32E-03	4.34E-03	4.25E-03
Control	2.02E-03	2.22E-03	3.11E-03	3.21E-03	5.40E-03	3.04E-03	3.10E-03
Manure Magic	2.92E-04	-4.70E-04	-8.43E-04	-8.99E-04	-3.40E-04	-9.39E-04	-7.65E-04
MOC - 7	2.99E-03	2.89E-03	2.44E-03	1.61E-03	1.60E-03	1.83E-03	2.13E-03
More Than Manure	3.94E-03	3.95E-03	3.73E-03	4.25E-03	4.85E-03	3.88E-03	3.91E-03
Sludge Away	3.58E-03	3.12E-03	2.71E-03	2.94E-03	3.44E-03	3.28E-03	2.86E-03
Sulfi-Doxx	2.12E-03	2.78E-03	1.72E-03	2.47E-03	1.37E-03	2.87E-03	2.51E-03
Days after dosing							
1	0.835	0.849	0.871	0.859	0.843	0.854	0.846
2	0.838	0.860	0.888	0.878	0.862	0.869	0.855
5	0.862	0.873	0.911	0.898	0.896	0.893	0.881
10	0.891	0.888	0.918	0.918	0.897	0.912	0.899
14	0.886	0.897	0.918	0.909	0.901	0.904	0.891
21	0.902	0.917	0.943	0.935	0.925	0.928	0.915
32	0.928	0.938	0.957	0.949	0.948	0.944	0.932
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ANOVA (P > F)							
Additive (mean)	0.338	0.349	0.518	0.613	0.212	0.498	0.554
Additive (slope)	0.578	0.504	0.486	0.400	0.343	0.561	0.543
Time	**3.98E-12**	**1.96E-12**	**9.3E-11**	**1.38E-10**	**1.55E-11**	**1.42E-10**	**2.83E-12**
Additive (mean) x time	0.761	0.592	0.346	0.444	0.342	0.675	0.706

Table 3.10 continued:

	B mg/L	EC mg/L	pH mg/L	DM mg/L
Additive (Mean)				
Coban 90	0.901	1.053	0.981	0.906
Control	0.902	1.041	0.984	0.892
Manure Magic	0.902	1.031	0.983	0.952
MOC - 7	0.938	1.012	0.983	0.951
More Than Manure	0.906	1.020	0.982	0.936
Sludge Away	0.937	1.021	0.979	0.944
Sulfi-Doxx	0.956	1.018	0.986	0.908
Additive (Slope)				
Coban 90	4.64E-03	-1.66E-03 b	6.55E-04	1.56E-03
Control	2.93E-03	-2.02E-03 b	3.79E-04	2.07E-03
Manure Magic	-6.01E-04	-8.50E-04 a	5.02E-04	2.41E-03
MOC - 7	2.84E-03	-6.30E-04 a	4.58E-04	1.69E-03
More Than Manure	4.39E-03	-3.20E-04 a	3.14E-04	2.38E-03
Sludge Away	4.44E-03	-1.30E-04 a	7.22E-04	1.68E-03
Sulfi-Doxx	2.16E-03	-5.90E-04 a	3.09E-04	4.00E-03
Days after dosing				
1	0.865	1.036	0.977	0.891
2	0.885	1.045	0.977	0.883
5	0.893	1.038	0.975	0.909
10	0.904	1.034	0.977	0.922
14	0.909	1.032	0.981	0.916
21	0.943	1.026	0.985	0.933
32	0.963	1.012	0.990	0.962
40	1.000	1.000	1.000	1.000
ANOVA (P > F)				
Additive (mean)	0.785	0.931	0.606	0.091
Additive (slope)	0.341	**0.007**	0.528	0.514
Time	**3.78E-12**	**6.63E-05**	**1.04E-16**	**3.58E-15**
Additive (mean) x time	0.179	0.858	0.056	0.157



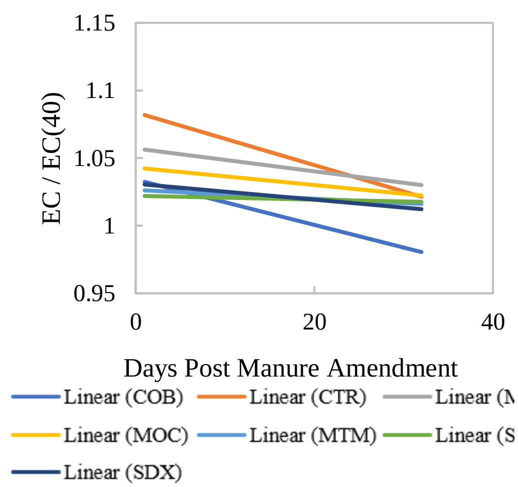


Figure 3.13: Statistically significant trends of the physical properties of the manure slurry in the additives experiment. Normalized data series are given in the left column and linear regressions are displayed in the right.

3.10 Physical Manure Properties from Disinfectant Experiment, Normalized

pH, TVS, and TDS all demonstrate significant differences with respect to treatment. pH and TVS demonstrates differences in slope, while TVS demonstrates differences in both mean and slope. For pH, *Pi-Quat* and *Virkon* treatments are statistically similar, but demonstrate positive slopes while all other treatments yielded similar negative slopes. For TVS, *Chlorine*, *Pi-Quat*, and *Virkon* treatments are statistically similar to the control. *Tek Trol* is the only statistically different treatment, having a greater slope than the treatment. *Tek Trol* also is statistically similar to the *Pi-Quat* treatment. These results are shown in Figure 3.13 and Table 3.10.

TDS demonstrates statistically significant differences in treatment for both slope and mean. *Virkon* is the only treatment showing a difference from control relative to series slope, being less than all other treatments. The *Chlorine* treatment is the only to show differences from the Control relative to series mean and is also greater than all other treatments. For MC, both *Pi-Quat*, and *Tek Trol* demonstrate lesser slopes than the Control. *Chlorine* and *Virkon* treatments are statistically similar to the Control.

Time is a statistically significant effect for all constituents except pH, TDS and interactive effects are found for pH, TDS, and MC.

Table 3.11: Isolated effect of time and treatment on physical properties of the manure slurry in the disinfectants experiment.

	pH	DO mg/L	COD mg/L	TS mg/L	TVS mg/L	TSS mg/L	TDS mg/L	MC
Additive (Mean)								
Chlorine	0.990	2.250	1.089	0.992	1.022	0.869	0.959 a	1.004 a
Control	0.991	2.594	0.864	0.978	1.010	1.012	0.975 a	1.005 a
Pi-Quat	0.997	1.341	0.909	0.950	0.960	0.969	0.954 a	1.007 b
Tek Trol	0.992	1.466	0.858	0.992	1.013	0.839	0.952 a	1.004 a
Virkon	1.008	1.531	0.922	0.989	1.031	0.874	0.814 b	1.004 a
Additive (Slope)								
Chlorine	-1.76E-03 b	9.24E-03	-1.43E-03	-4.70E-04	-1.85E-03 c	-1.25E-03	-1.44E-02 b	9.24E-03
Control	-2.04E-04 b	1.04E-03	2.08E-03	5.41E-04	-5.88E-04 bc	4.22E-03	-3.68E-03 a	1.04E-03
Pi-Quat	8.60E-04 a	9.60E-03	-3.77E-03	7.76E-04	4.90E-04 ab	3.45E-03	-8.94E-03 ab	9.60E-03
Tek Trol	-2.58E-04 b	8.51E-03	6.68E-04	1.80E-03	1.60E-03 a	3.63E-03	-5.22E-03 a	8.51E-03
Virkon	3.45E-03 a	-1.90E-02	-1.97E-03	4.70E-04	-9.33E-04 bc	-2.70E-03	-7.35E-03 a	-1.90E-02
Days after dosing								
1	0.97	2.49	0.876	0.984	1.020	0.838	1.120	2.485
2	1.02	1.45	0.883	0.960	0.999	0.909	1.000	1.450
5	0.99	1.45	1.027	0.970	1.008	0.952	1.088	1.445
10	1.00	2.23	0.941	0.981	1.015	0.860	0.769	2.225
14	0.99	2.21	0.845	0.984	1.018	0.895	0.804	2.210
21	0.98	2.10	0.983	0.963	0.989	0.900	0.767	2.100
32	1.01	1.78	0.872	0.999	1.008	0.948	0.898	1.775
40	1.00	1.00	1.000	1.000	1.000	1.000	1.000	1.000
ANOVA (P > F)								
Additive (mean)	0.648	0.081	0.171	0.523	0.358	0.264	**0.030**	**0.020**
Additive (slope)	**0.035**	0.852	0.802	0.147	**0.032**	0.119	**0.026**	0.357
Time	0.038	**0.004**	**0.014**	**0.001**	**0.183**	**0.029**	0.000	**1.47E-13**
Additive (mean) x time	**0.010**	0.558	0.167	0.435	0.101	0.057	**2.19E-04**	**2.19E-04**

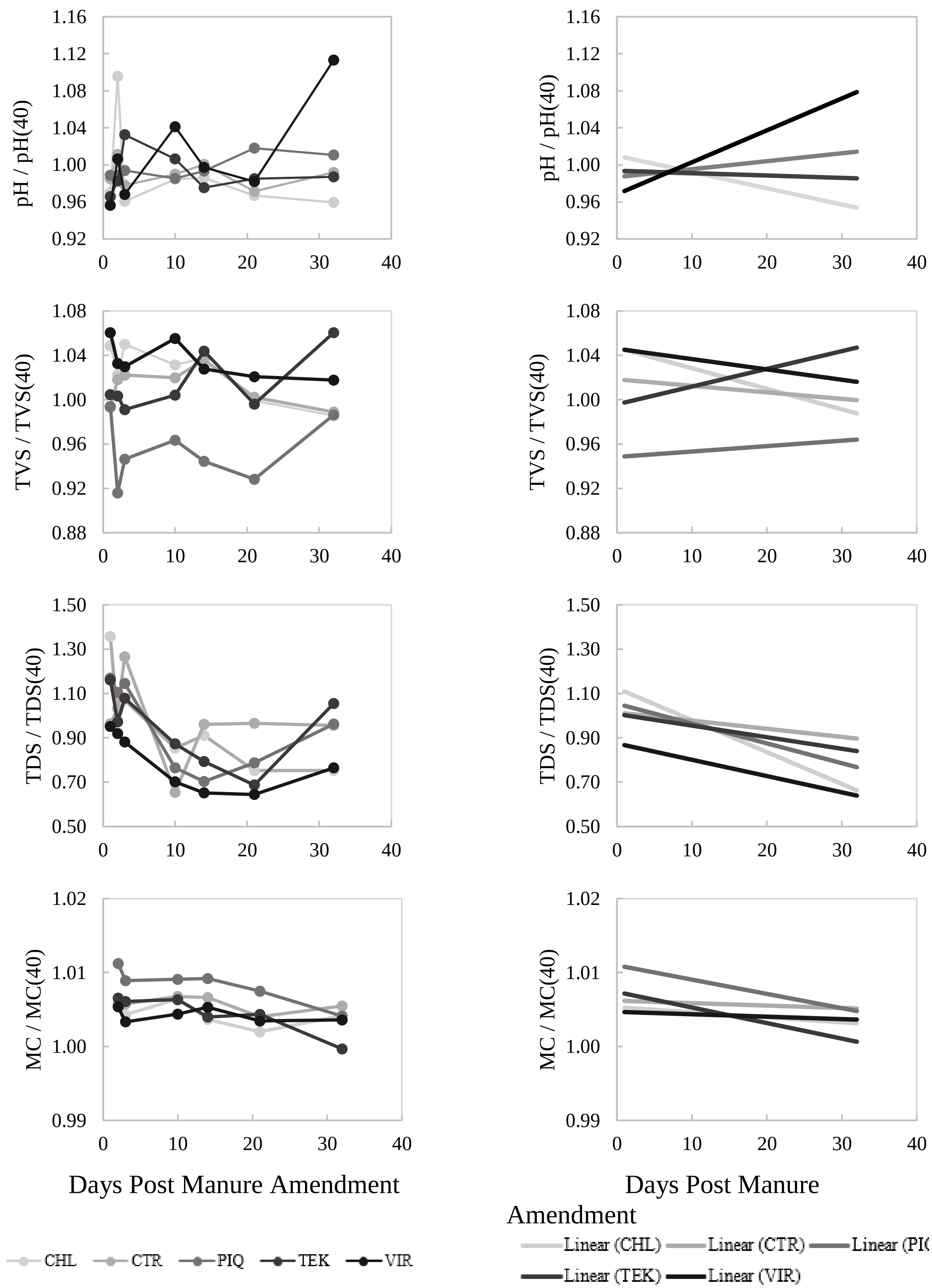


Figure 3.14: Statistically significant effects of slurry treatment on the normalized disinfectant experiment manure physical properties. Data is presented in the left column and linear regressions in the right.

3.11 Nutrient Content from Disinfectant Experiment, Normalized

Tot N, P, S, Fe, EC, and DM all demonstrate statistical significant differences with treatment. Tot N, P, S, Fe, EC, and DM were different with respect to mean and EC and DM were both different with respect to slope as well. These results are shown graphically in Figure 3.14 and tabularly in Table 3.11. For Tot N, *Chlorine* and *Virkon* treatments are statistically the same as the Control treatment. *Pi-Quat* and *Tek Trol* treatments are statistically lower. For P, *Tek Trol* and *Virkon* treatments have the same mean as the control treatment. The *Chlorine* treatment is statistically larger than the control while the *Pi-Quat* treatment is statistically less. *Chlorine*, *Pi-Quat*, and *Tek Trol* are the same, and *Chlorine*, *Tek Trol*, and *Virkon* are also the same.

Table 3.12: Isolated effect of time and treatment on nutrient content of the manure slurry in the disinfectants experiment.

	Org N mg/L	NH3-N mg/L	NO3-N mg/L	Tot N mg/L	P mg/L	K mg/L	S mg/L
Additive (Mean)							
Chlorine	0.990	2.250	1.089	0.961 c	0.911 ab	0.907	0.901 a
Control	0.991	2.594	0.864	0.954 c	0.871 c	0.881	0.817 c
Pi-Quat	0.997	1.341	0.909	1.038 a	0.914 a	0.911	0.928 a
Tek Trol	0.992	1.466	0.858	1.021 ab	0.895 abc	0.901	0.897 a
Virkon	1.008	1.531	0.922	0.963 bc	0.884 bc	0.891	0.857 b
Additive (Slope)							
Chlorine	-9.29E-03	8.98E-03	8.71E-04	1.22E-03	3.35E-03	3.24E-03	3.23E-03
Control	3.13E-03	-4.24E-03	7.11E-03	8.21E-04	2.69E-03	3.20E-03	2.53E-03
Pi-Quat	-2.66E-03	1.28E-03	-5.57E-03	-6.58E-04	2.54E-03	2.64E-03	1.65E-03
Tek Trol	2.54E-03	-4.43E-03	1.26E-02	-6.65E-04	3.10E-03	2.71E-03	2.60E-03
Virkon	4.45E-03	-3.94E-03	6.84E-02	1.13E-03	2.82E-03	2.82E-03	2.35E-03
Days after dosing							
1	0.937	1.073	1.046	0.979	0.857	0.857	0.842
2	0.999	1.051	0.698	0.989	0.850	0.856	0.833
5	1.032	1.031	1.127	0.994	0.856	0.862	0.853
10	0.969	0.992	0.924	0.972	0.867	0.873	0.850
14	0.919	1.078	0.955	0.975	0.879	0.881	0.855
21	1.006	1.002	1.012	0.991	0.905	0.906	0.891
32	0.969	1.050	1.581	0.999	0.944	0.950	0.917
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ANOVA (P > F)							
Additive (mean)	0.654	0.745	0.530	**0.041**	**0.046**	0.146	**0.005**
Additive (slope)	0.581	0.694	0.458	0.225	0.820	0.671	0.469
Time	0.803	0.976	0.334	**0.002**	**1.26E-21**	**9.81E-26**	**1.40E-17**
Additive (mean) x time	0.629	0.947	0.780	**2.76E-04**	0.322	0.569	**0.012**

Table 3.12 continued:

	Ca mg/L	Mg mg/L	Na mg/L	Zn mg/L	Fe mg/L	Mn mg/L	Cu mg/L
Additive (Mean)							
Chlorine	0.908	0.923	0.907	0.906	0.916 ab	0.908	0.906
Control	0.860	0.884	0.880	0.850	0.849 c	0.875	0.862
Pi-Quat	0.927	0.951	0.913	0.916	0.950 a	0.913	0.916
Tek Trol	0.884	0.883	0.894	0.894	0.888 bc	0.904	0.905
Virkon	0.864	0.894	0.892	0.880	0.887 bc	0.880	0.877
Additive (Slope)							
Chlorine	4.09E-03	3.33E-03	3.09E-03	3.10E-03	3.19E-03	3.28E-03	3.14E-03
Control	3.15E-03	2.50E-04	3.16E-03	2.11E-03	1.52E-03	3.10E-03	3.07E-03
Pi-Quat	2.84E-03	1.82E-03	2.65E-03	2.21E-03	2.20E-03	2.55E-03	2.80E-03
Tek Trol	3.47E-03	3.95E-03	3.01E-03	3.14E-03	4.01E-03	2.88E-03	2.81E-03
Virkon	3.09E-03	2.71E-03	2.79E-03	2.68E-03	2.02E-03	2.72E-03	2.62E-03
Days after dosing							
1	0.846	0.879	0.859	0.849	0.866	0.856	0.852
2	0.843	0.871	0.855	0.850	0.874	0.851	0.847
5	0.841	0.860	0.858	0.851	0.847	0.860	0.861
10	0.851	0.879	0.872	0.860	0.864	0.866	0.860
14	0.877	0.908	0.878	0.872	0.889	0.880	0.875
21	0.912	0.918	0.908	0.905	0.898	0.910	0.911
32	0.940	0.941	0.949	0.928	0.946	0.944	0.938
40	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ANOVA (P > F)							
Additive (mean)	0.070	0.206	0.116	0.054	**0.040**	0.186	0.106
Additive (slope)	0.822	0.551	0.864	0.686	0.610	0.688	0.918
Time	**3.52E-16**	**8.44E-07**	**7.60E-24**	**4.68E-18**	**1.08E-09**	**4.01E-23**	**6.04E-21**
Additive (mean) x time	0.178	0.357	0.331	0.129	0.304	0.344	0.224

Table 3.12 continued:

	B mg/L	EC mg/L	pH mg/L	DM mg/L
Additive (Mean)				
Chlorine	0.848	0.992 c	0.994	0.944 a
Control	0.924	0.990 c	0.997	0.927 abc
Pi-Quat	0.855	1.088 a	1.000	0.911 c
Tek Trol	1.077	1.049 b	0.994	0.921 bc
Virkon	0.852	0.995 c	0.994	0.930 ab
Additive (Slope)				
Chlorine	4.77E-03	3.17E-04 a	-8.93E-05	1.65E-03 b
Control	2.36E-03	5.79E-04 a	-3.80E-05	1.27E-03 b
Pi-Quat	1.57E-03	-2.33E-03 b	0.00E+00	2.73E-03 a
Tek Trol	1.00E-02	-2.35E-03 b	-5.23E-04	2.36E-03 a
Virkon	3.85E-03	-4.96E-04 a	-1.98E-04	1.38E-03 b
Days after dosing				
1	0.886	1.035	0.997	0.899
2	0.824	1.031	0.995	0.892
5	0.885	1.033	1.000	0.910
10	0.889	1.035	1.000	0.905
14	0.870	1.027	0.992	0.914
21	0.913	1.009	0.987	0.940
32	1.022	1.011	0.996	0.954
40	1.000	1.000	1.000	1.000
ANOVA (P > F)				
Additive (mean)	0.287	**0.002**	0.795	**0.042**
Additive (slope)	0.589	**0.004**	0.127	**0.008**
Time	**0.014**	1.96E-03	**1.21E-04**	1.57E-26
Additive (mean) x time	0.697	**6.74E-04**	**0.026**	**4.15E-04**

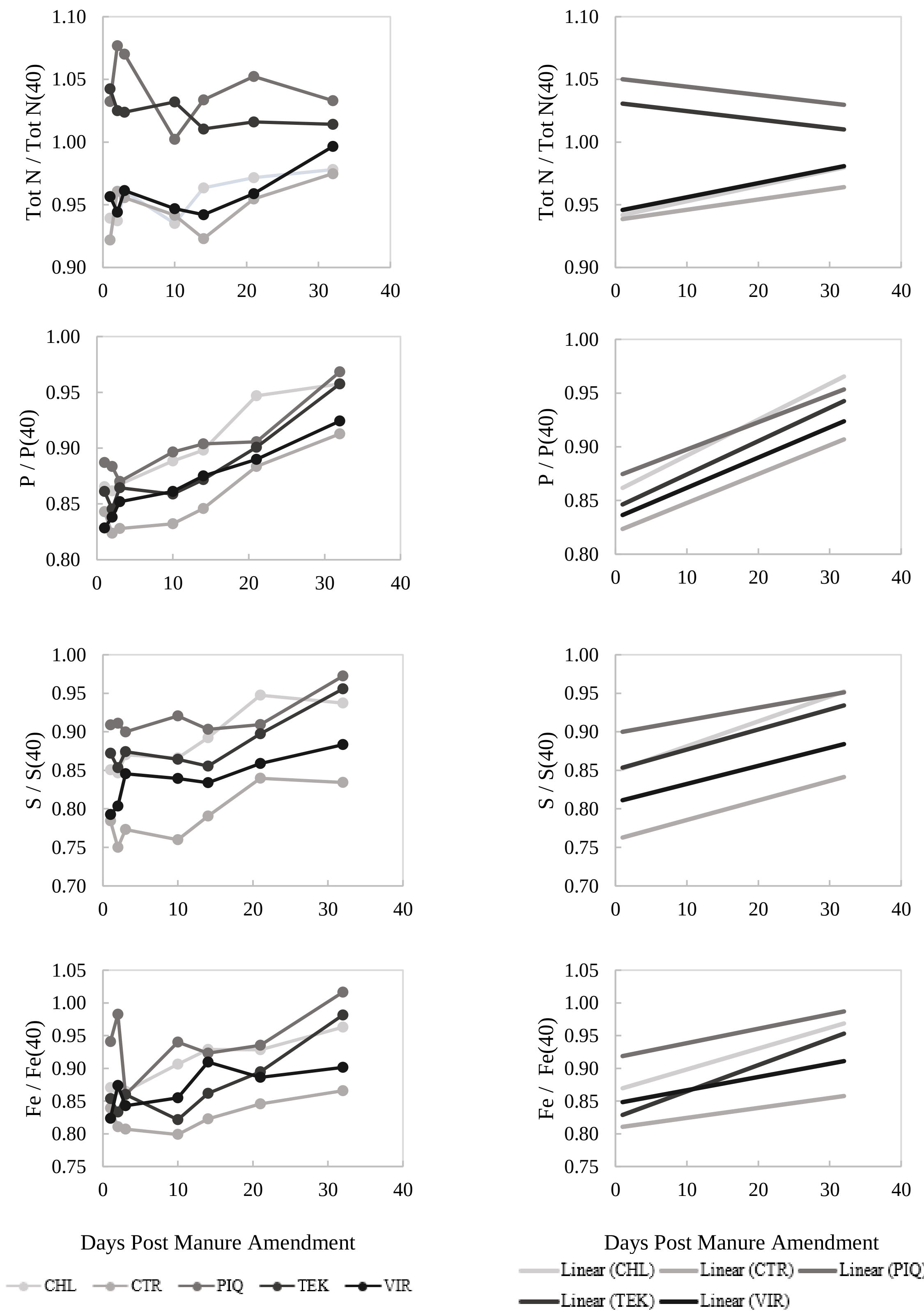


Figure 3.15: Effects of slurry treatment on normalized disinfectant experiment nutrient content. Data is presented in the left column and linear regressions in the right.

3.12 Antibiotics Data from both Experiments, Normalized

Table 3.12 displays the results for the ANOVA over the antibiotics concentrations for the additives experiment. While chlortetracycline and lincomycin both demonstrated statistically significant effects for the un-normalized data, only tiamulin demonstrates a significant treatment effect for the normalized data. For tiamulin, only the *Coban 90* treatment differs from the control treatment, being greater than control and all other treatments except *Manure Magic*. These relationships are shown in Figure 3.15. It is worth noting that while the slopes for tiamulin listed in Table 3.12 are positive, the slopes in Figure 3.15 for tiamulin are negative. This is because the slopes listed in Table 3.12 are the result of averaging the slopes of each replicate time series for each antibiotic while the data shown in Figure 3.15 is the result of averaging the replicate time series and taking the slope of the resulting time series. These two procedures yield different results.

Table 3.13: Isolated effect of treatment on the antibiotics results for the additives experiment.

	Chlortetracycline ng/g	Lincomycin ng/g	Tiamulin ng/g
Additive (Mean)			
Coban 90	1.177	2.549	1.116 a
Control	0.505	0.556	0.491 b
Manure Magic	1.073	2.760	0.682 ab
MOC-7	0.651	0.661	0.253 b
More Than Manure	0.679	0.646	0.309 b
Sludge Away	0.654	0.691	0.365 b
Sulfi-Doxx	0.778	1.389	0.306 b
Additive (Slope)			
Coban 90	-0.825	1.962	0.309
Control	-0.346	-1.142	0.116
Manure Magic	-0.661	-9.374	1.879
MOC-7	0.454	-0.117	0.685
More Than Manure	-0.269	0.353	0.830
Sludge Away	-0.405	-0.265	1.299
Sulfi-Doxx	-0.345	-0.056	0.621
Days after dosing			
1	0.773	0.912	0.599
5	0.909	1.672	0.737
14	0.737	0.945	0.281
21	0.733	1.867	0.394
40	1.000	1.000	1.000
ANOVA (P > F)			
Additive (mean)	0.208	0.477	**0.030**
Additive (slope)	0.359	0.439	0.724
Time	0.530	0.302	**0.005**
Additive (mean) x time	0.954	0.501	0.481

Table 3.13 displays the results of the ANOVA and growth curve analysis for the normalized antibiotics levels in the disinfectant experiment. As with the original antibiotics data from the disinfectant experiment, tiamulin demonstrates a statistically significant treatment effect for the mean of the normalized series. *Virkon* is statistically

greater than the Control mean and all other treatments are statistically similar. These relationships are shown in Figure 3.16. A time and interactive effect is also demonstrated once again for tiamulin.

Table 3.14: Isolated effect of treatment on the antibiotics results for the disinfectants experiment.

	Chlortetracycline ng/g	Lincomycin ng/g	Tiamulin ng/g
Additive (Mean)			
Chlorine	0.834	0.648	0.464 a
Control	0.716	0.735	0.484 a
Pi-Quat	0.807	1.702	0.781 a
Tek Trol	0.892	0.476	1.394 b
Virkon	3.395	1.165	0.611 a
Additive (Slope)			
Chlorine	0.673	0.470	0.375
Control	0.133	-0.104	0.026
Pi-Quat	-0.018	-1.107	1.048
Tek Trol	0.418	-0.535	1.067
Virkon	-9.169	1.404	2.076
Days after dosing			
1	0.946	0.436	0.551
5	2.898	0.854	0.440
14	0.829	1.310	0.588
21	0.971	1.125	1.409
40	1.000	1.000	1.000
ANOVA (P > F)			
Additive (mean)	0.381	0.290	**0.041**
Additive (slope)	0.650	0.199	0.419
Time	0.574	0.194	**5.17E-06**
Additive (mean) x time	0.582	0.546	**6.65E-03**

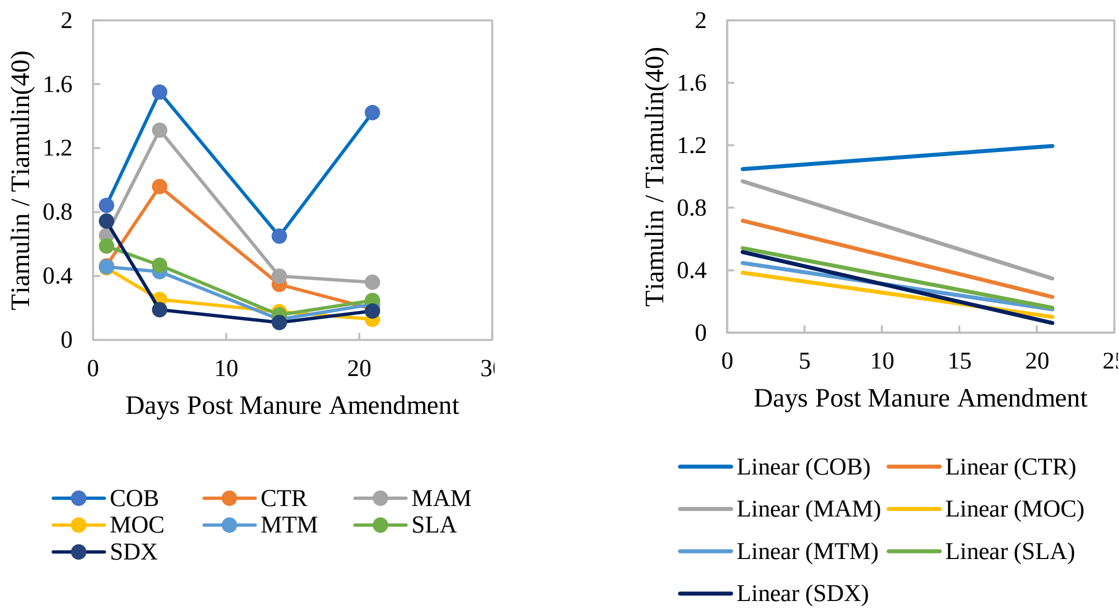


Figure 3.16: Statistically significant effects of slurry treatment on normalized additive experiment antibiotics concentrations. Data is presented in the left column and the linear regressions in the right.

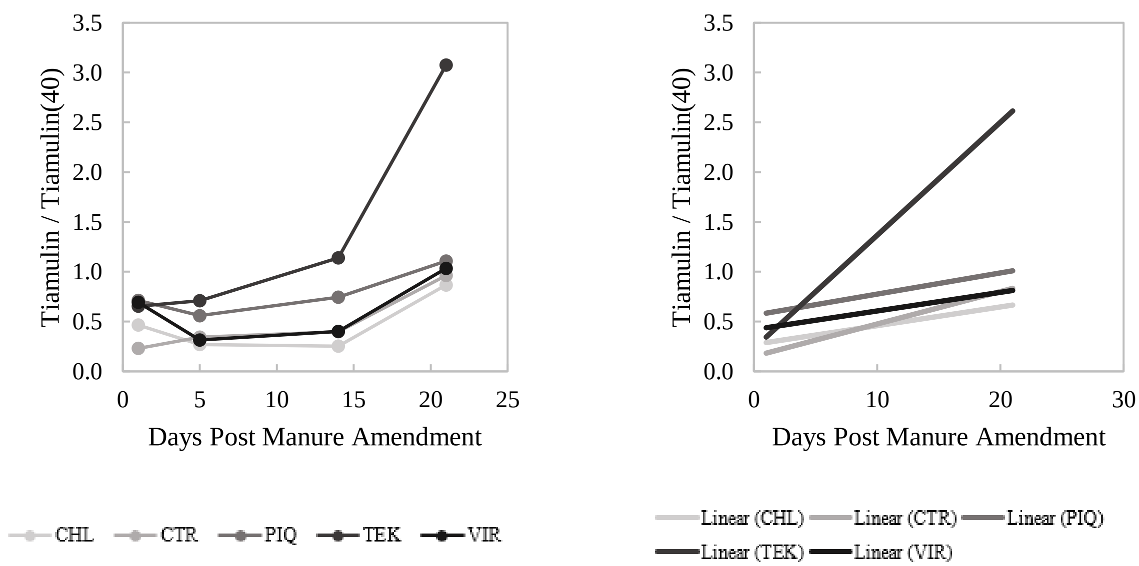


Figure 3.17: Statistically significant effects of slurry treatment on normalized disinfectant experiment antibiotics concentrations. Data is presented in the left column and the linear regressions in the right.

Chapter 4: Discussion

4.1 Compilation and Organization of Results

The primary goal of the data processing methods employed was to isolate the effect of treatment from the combined effects of treatment and evaporation. This was done by normalizing all data time series by the final time point of each series, then comparing the slope and mean of each series to that of the control treatment. Results from the LSD tests performed on the slopes and means showed a reduction in statistically significant treatment effects between the original and normalized data. This indicates many of the statistically significant treatment effects found from ANOVA of the original data were not due to slurry amendment, but rather were caused by evaporation from the bioreactors. Table 4.1 highlights the reduction in significant treatment effects for the additive and disinfectant experiments.

In the additives experiment, it is clear from Table 4.1 that the normalization resulted in a large decrease in statistically significant treatment effects. The original data produced eighteen significant treatment effects while the normalized data only produced three. In the original data, *MOC-7* and *Sulfi-Doxx* are significant 19 times each, *More Than Manure* is significant 17 times *Sludge Away* is significant 18 times, and *Coban 90* and *Manure Magic* are significant 7 times each. In the normalized data *Coban 90* and *Sludge Away* appears twice and all other treatments appear once as significant.

In the disinfectants experiment there are 9 instances of statistically significant treatment effects with the original data. *Chlorine*, *Pi-Quat*, *Tek Trol*, and *Virkon* appear as significant effects 5, 6, 7, and 6 times, respectively in the original data. For the normalized data there are 9 instances. *Chlorine*, *Pi-Quat*, *Tek Trol*, and *Virkon* appear 5, 4, 5, and 3 times, respectively in the normalized data.

It is not clear why no decrease in frequency of treatment effects occurred between original and normalized data for the disinfectant experiment. Nor is it clear why there are far fewer instances of treatment effect in the original disinfectants data than there are in the additives data. One item to note is that for the normalized data, two criteria were used to distinguish treatments from control (slope and mean), whereas for the original data only one criteria was used (mean). This may explain why no decrease in treatment effects is observed in the disinfectant experiment, but does not explain the large decrease observed in the additives experiment.

Figure 4.1: Summary of treatment effects for both additive and disinfectant experiments.

	Treatment Effect?			
	Additives Experiment		Disinfectants Experiment	
	Original	Normalized	Original	Normalized
pH	MOC, SDX	None	None	None
DO	None	SLA	None	None
COD	MAM, MOC, MTM, SLA, SDX	None	None	None
TS	MOC, MTM, SLA, SDX	None	PIQ, TEK, VIR	None
TVS	MOC, MTM, SLA, SDX	None	CHL, PIQ, TEK, VIR	TEK
TSS	COB, MOC, MTM, SLA, SDX	COB	PIQ, VIR	None
TDS	None	None	VIR	CHL, VIR
MC	MOC, MTM, SLA, SDX	None	CHL, PIQ, TEK, VIR	None
Org N	None	None	None	None
NH3-N	None	None	None	None
NO3-N	None	None	CHL, TEK, VIR	None
Tot N	MAM, MOC, MTM, SLA, SDX	None	None	PIQ, TEK
P	COB, MAM, MOC, MTM, SLA, SDX	None	None	CHL, PIQ
K	None	None	None	None
S	MOC, MTM, SLA, SDX	None	None	CHL, PIQ, TEK, VIR
Ca	MOC, MTM, SLA, SDX	None	None	None
Mg	COB, MAM, MOC, MTM, SLA, SDX	None	None	None
Na	None	None	CHL, TEK	None
Zn	COB, MAM, MOC, MTM, SLA, SDX	None	None	None
Fe	MOC, MTM, SLA, SDX	None	None	CHL, PIQ
Mn	MOC, MTM, SLA, SDX	None	None	None
Cu	COB, MAM, MOC, MTM, SLA, SDX	None	None	None
B	MOC, MTM, SLA, SDX	None	None	None
EC	COB, MAM, MOC, MTM, SLA, SDX	MAM, MOC, MTM, SLA, SDX	PIQ, TEK	PIQ, TEK
DM	COB, MAM, MOC, MTM, SLA, SDX	None	None	PIQ, TEK
CTC*	MOC, MTM, SLA, SDX	None	None	None
LMN*	COB	None	None	None
TMN*	None	COB	CHL, PIQ, TEK	VIR

*CTC = chlortetracycline
LMN = Lincomycin
TMN = Tiamulin

4.2 Discussion of Additives Experiment

In the additives experiment, DO, TSS, and EC were the three constituents demonstrating statistically significant treatment effects. Interestingly, DO exhibited a significant effect with the normalized data but not with the original data. *Sludge Away* was the only treatment with significant differences for DO. With the *Sludge Away* treatment, the DO concentrations exhibit a slope roughly twice that of the control. From Figure 3.10, the series for *Sludge Away* in the plot for DO appears to be generally decreasing, as do the other series. The *Sludge Away* series differs from the other treatment series in that the day 1 and day 21 points are significantly higher than any other datapoint.

The generally decreasing trend can be explained by the rate of sampling over the course of the incubation. Before each sample is taken, the pH and DO of each reactor is taken, and then the reactor is mixed thoroughly to ensure a uniform sample is taken. This mixing introduces oxygen into the reactors. Because the time between sampling increases over the course of the experiment, the reactors have more time to re-establish anaerobic conditions through oxygen consumption by facultative bacteria. This is the most likely explanation for the decreasing trend in DO verses time. The *Sludge Away* data follows this trend as well, apart from one abnormally high data point on sampling day 21. This anomalous point could likely be due to premature convergence by the DO probe or a false reading due to a layer of foam trapped between the probe and it's protective cage.

The two other statistically significant treatments are TSS and EC, which are compound physical properties of the manure. It makes sense both of these constituents are significant because they both provide composite measurements of the quantity of dissolved matter in the slurry. Moreover, MAM, MOC, MTM, SLA, and SDX are statistically significant treatments for EC, while only COB is significant for TSS. Unfortunately, the composite nature of these constituents makes it difficult to pinpoint specific characteristics of these treatments which may be responsible for the trend. It is interesting however, that COB is the only treatment to appear as significant for TSS (being greater than the control) and the only treatment to not appear as significant for EC (all other treatments produce more positive slopes than control). Because TSS provides a measure for particulate matter and EC provides a measure for soluble matter, it makes sense that no treatment showed effects for both constituents.

To better understand the results for the additive experiment, or the lack thereof, a more in depth discussion of the additive treatments is required. Detailed information about many additives and disinfectants has been acquired from the manufacturers or from the literature, however the active ingredients for several treatments are proprietary to the manufacturer.

Coban 90 only produces a statistically significant effect for TSS. As discussed in the Methods and Materials chapter, *Coban 90*, for which Sodium Monensin is the active ingredient, is not manufactured as a pit additive, which also distinguishes it from other treatments. Instead it is produced as a treatment to prevent coccidiosis, which is caused by intestinal foaming, in poultry. Monensin's mode of action is to alter the microbial composition of the rumen to increase propionic acid production, thereby decreasing acetic acid production which is a precursor to methane. Because no previous research has been found investigating the effect of manure pit additives on antibiotics fate it is difficult to predict possible explanations for why Coban produces a treatment effect. The problem is also complicated by the fact that the data does not fit a decay model, as might be predicted. High variability in measured tiamulin concentration means this trend may very well be due to chance and it is better not to read too far into the data.

Active ingredient information for *Manure Magic* and *MOC-7* are proprietary.

More Than Manure consists of a maleic-itaconic copolymer as a partial salt with calcium and ammonium. Maleic-itaconic copolymers have been investigated as means for reducing ammonia emissions from manure and fertilizer by way of urease inhibition which slows conversion of urea to ammonia (Chen, et. al, 2013; Chien S.H. et. al., 2014; Goos, 2013). This mechanism could be expected to manifest itself in a lower NH_4-N concentration compared to other treatments. This trend is not shown in the data; only TSS and EC are constituents for which *More Than Manure* is a significant treatment. Chen et. al (2013) was able to measure a significant decrease in ammonia volatilization from dairy manure after treatment with *More Than Manure*. The dosages of *More Than Manure* used by Chen et. al. are significantly larger than the *More Than Manure* dose used in the additives experiment. The lowest dosage applied by Chen et. al was 0.5 mL product per L of manure, as compared to the 0.06 mL product per L manure used for *More Than Manure* in the additives experiment. This lower dosage is the most likely reason for the lack of significant decrease in NH3-N concentration with the *More Than Manure* treatment.

Sludge Away contains many strains of anaerobic bacteria for the purposes of carbon fixation, sulfate removal, nitrogen fixation, and denitrification. Anaerobic sulfate removers found in *More Than Manure* are *Desulfovibrio aminophilus* and *Desulfovibrio vulgaris*. Anaerobic nitrogen fixers are Anaerobacter polyendosporus, Clostridium butyricum, and Methanomethylovorans hollandica. *Wolinella succinogenes* is present as an anaerobic denitrifier (Certification of Free Sales, n.d.). With the presence of several species sulfate removers and denitrifiers, it could be expected to see an increase in the organic nitrogen content. Additionally the presence of *Wolinella succinogenes* may indicate an expected decrease in NO_3-N. As can be seen in Figure 4.1, none of these trends are present in the data. Instead, TSS and EC are the only constituents for which *More Than Manure* was considered a significant treatment.

Sludge Away also contains of a wide consortium of purple sulfur bacteria. These bacteria are widely known to decrease odor in manure wastewaters (Koelsch et. al, 1997). These bacteria oxidize H_2S to sulfate or elemental sulfur. Thus manure amended with a treatment of purple sulfur bacteria may be expected to experience higher sulfur concentrations than a control due to less sulfur loss due to volatilization of H_2S. In addition to oxidation of odorous sulfur compounds, *Sludge Away* is marketed towards solids reduction and nutrient retention. Nutrient retention and reduction in TS was not observed relative to the control, but an increase in TSS and EC was observed for *Sludge Away* treatments, indicating a possibility of solubilization of particulates in the slurry.

Many other species of bacteria are listed on the *Sludge Away* label. Of these, *bacillus subtilis*, *bacillus licheniformis*, and *bacillus amyloliquefaciens* appear to have significant research regarding their effect on swine manure. A 2015 study found *Bacillus licheniformis* effectively reduced ammonia emissions in swine manure (Lim et. al, 2015). *Bacillus licheniformis* has also been found to convert NH_3-N to organic nitrogen content (Hoppensack, 2002). Direct application of *Bacillus amyloliquefaciens* has been found to be proficient in emissions reduction of NH_3, H_2S, and SO_2 (Ahmed, et. al, 2014). This research also may indicate the potential for *Sludge Away* to demonstrate differences from the control in terms of NH_3-N, organic nitrogen, and sulfur, however none of these trends were demonstrated as part of the additive experiment. *Sludge Away* showed significant effects for DO, TSS, and EC. As discussed above, the trend with DO may be likely due to an anomalous data point.

Sulfi-Doxx consists of bacillus bacteria and Trichoderma fungi in a liquid humate carrier. Product literature does not say what specific strains of bacillus or Trichoderma are present. Without a more detailed ingredients list it is difficult to speculate on possible modes of action to explain the effects of *Sulfi-Doxx* in the additives experiment. *Sulfi-Doxx* is marketed as reducing hydrogen sulfide emissions. As such, an expected effect could be a reduction in sulfur concentration. Once again, this effect is not observed for *Sulfi-Doxx*. As with all additive treatments besides *Sludge Away*, *Sulfi-Doxx* only produced a significant effect for EC.

All treatments which produce statistically significant effects for EC claim to improve liquefaction of manure through treatment. Solubilization of particulate matter in the slurry during liquefaction would theoretically produce a decrease in TSS or an increase in TDS or EC. Though MAM, MOC, MTM, SLA, and SDX all produce statistically significant increases in slope for EC, no corresponding increase in either mean or slope was seen for TDS nor was a corresponding decrease seen in TSS. Thus the results cannot fully confirm any product fulfilled its promise of increased liquefaction. Nor can the additives experiment confirm any marketed claim to nutrient preservation.

4.3 Discussion of Disinfectants Experiment

There are significantly more additive effects in the normalized results for the disinfectant experiment than there was in the additives experiment. As with the additives results, a closer look at each disinfectant will be provided in this section in an attempt to further explain these results.

Chlorine is a halogen based disinfectant product. The mechanism of *Chlorine* disinfection involves an increase in cell membrane permeability which results in a loss of cytoplasmic material and an influx of *Chlorine* into the cell (Benjamin, et. al, 2013). The later results in damage to cell DNA. Some research has been completed investigating the effects of chlorination on antibiotic resistance genes in swine manure. No research could be found characterizing the effect of *Chlorine* disinfection on manure nutrient content or on antibiotics fate. Sulfur and iron both experienced treatment effects from *Chlorine*. For sulfur, *Chlorine* demonstrates a higher mean normalized concentration than the control (0.901 versus 0.817). For iron, *Chlorine* also demonstrates a higher mean normalized concentration than the control treatment.

Pi-Quat is a quaternity ammonium cation type disinfectant. The disinfection mechanism involves penetration of the cell wall, causing cellular leakage and cell death (Ioannou et. al, 2006). P, S, Fe, EC, and DM all demonstrated significance with *Pi-Quat* as a treatment. For each of these four constituents, *Pi-Quat* demonstrated a statistically higher normalized mean than the control treatment. EC and DM demonstrated differences from the control with respect to both mean and slope. For EC, *Pi-Quat* demonstrated a greater normalized mean and more significantly more negative slope than the control treatment. For DM, *Pi-Quat* was statistically similar to the control mean but demonstrated a greater slope than that of the control treatment.

Tek Trol is a phenol based product. Method of disinfection for phenolic compounds also involves cell lysis, however not via penetration of the cell wall. The phenolic compounds instead inhibits intracytoplasmic enzymes and in high concentrations causes denaturation of bacterial proteins and cell lysis (Maris, 1995). *Tek Trol* demonstrates treatment differences in TVS, Tot N, S, EC and DM. For TVS, *Tek Trol* demonstrates a significantly higher slope than that of the control treatment (1.80E-3 verses -5.88E-4). *Tek Trol* demonstrates a greater normalized mean than the control treatment for Tot N, and Sulfur. A greater mean and more negative slope is observed with EC for *Tek Trol*. For DM, the normalized mean is statistically similar to that of the control but the normalized slope is statistically roughly double that of the control treatment.

Virkon is an oxidant type disinfectant with potassium peroxymonosulfate as the active ingredient. *Virkon* disinfects by oxidizing the sulfur bonds of proteins and enzymes, resulting in the disruption of cell membrane function and its eventual rupture (*Virkon*, n.d.). Though *Virkon* itself has not been studied with respect to manure constituents or antibiotics fate, other oxidants, notably ozone. TDS, S, and tiamulin are all statistically significant treatment effects for *Virkon*. For TDS, *Virkon* demonstrates a lower normalized mean than the control and all other treatments. It also demonstrates more negative slope than the control treatment. For S, *Virkon* demonstrates a statistically greater mean than for the control treatment. For tiamulin, *Virkon* demonstrates a significantly higher mean from the control treatment as well. As no previous research has been found investigating the effect of disinfectant products on antibiotics fate it is difficult to speculate on why *Virkon* had an effect. This is also complicated by the fact that the data does not follow any sort of expected decay, nor does it stay constant. As with the additives experiment, it may be better to not read too far into the data, given the high variability of the measured tiamulin concentrations.

Given that each of these disinfectant products (though there active ingredients differ) disinfects by disrupting the cell wall resulting in cell lysis, it would be expected that they would demonstrate treatment effects with more or less the same constituents. This is somewhat the case as many constituents demonstrated treatments effects with more than one treatment. Sulfur is the only constituent having more than two simultaneous treatment effects however. TVS and tiamulin both have only one treatment effect. Further research is needed to determine mechanisms by which these disinfectant products may influence swine manure physical and chemical properties as well as antibiotics fate.

Chapter 5: Conclusion

In the experiments discussed in this thesis, swine manure slurry was incubated over a 40 day period and the effect of common manure pit additives and swine facility disinfectants were assessed on the slurry physical properties, nutrient content, and antibiotics concentrations. Evaporation from the slurry bioreactors turned out to be a significant factor affecting changes in manure constituents. Concentrations were normalized by day 40 values to allow for isolation of treatment effects. Normalization resulted in a large decrease in number of significant treatment effects for the additives experiment but did not result in a significant change in treatment effects for the disinfectants experiment. Coban and *Virkon* had significant treatment effects on tiamulin concentrations for the additives and disinfectants experiments, respectively. However, the reported antibiotics concentrations were highly variable and did not fit zero or first order decay models. Thus these treatment effects should be carefully considered.

The main lesson from the additives and disinfectants experiment is to plan for accounting for evaporation from the reactors. If planning had taken place to account for evaporation, an extra control reactor could have been filled for the sole purpose of measuring the liquid level at each sampling time. This would have aided greatly in determining how much evaporation took place over the course of the experiment. With sufficient evaporation data, the original data could be corrected to account directly for the evaporation and normalization would not be necessary. This would cut down on the amount of data analysis necessary and produce results which would correspond more closely to physical reality.

A second lesson learned is to ensure the manure is well mixed in all reactors before the experiment begins. When manure is pumped from deep pit storage at the production facility, the sump pumps more liquid manure early, but will tend to pull thicker manure the longer it runs. Because of this, some 5-gallon buckets will contain more liquidous slurry than others. When distributing slurry from the 5-gallon buckets to the reactors, make sure to distribute some manure from each bucket into each of the reactors as randomly as possible. This ensures the manure in each reactor is fully representative of the sample taken from the production facility. During a preliminary experiment, this was not done adequately enough, and a large variability appeared between the baseline slurry in various reactors. For the additives experiment a better job was done, however a small discrepancy in baseline moisture content of several reactors was still present. In the disinfectants experiment, finally, an adequate job of manure distribution into the reactors was done.

A more minor lesson was with regards to pH and DO measurement in the slurry reactors. In reactors with a heavy layer of foam on top, the foam would tend to coat the outside of the pH and DO probes, and could sometimes result in slow convergence or inaccurate readings. In such cases it was effective to give the probes a vigorous shake while submerged in the slurry to agitate off the foam. Most of the time this would result in a faster and more accurate reading.

For many of the results of these experiments further research is needed to justify or explain. First, further research needs to be completed investigating the effect of both additive and disinfectant products on the fate of antibiotics residuals. Research in this area is currently lacking. To start, more studies need to be completed investigating the effects of additive and/or disinfectant products on antibiotics levels as a whole. Once results accumulate, products of interest can be investigated further in lab scale studies by looking into individual active chemical or bacterial species of interest. For example, the bacterial species *Bacillus subtilis* and *Bacillus licheniformis* are both present in *More Than Manure* as organic waste degraders and have been the subject of some research interest with regard to ammonia volatilization. They have also been found to be resistant to *Chlorine* disinfection in the presence of chlortetracycline (Adams, et. al, 2005).

Another opportunity for future research is to identify the combined effects of additive and disinfectant products both on manure composition as well as on antibiotics fate. Use of disinfectant products can theoretically alter the effectiveness of an additive product though alteration of the microbial community. Overuse of disinfectants can also result in resistant strains of bacteria, which can be investigated alongside antibiotic resistance. This research opportunity requires a greater understanding of both additive and disinfectant products as they pertain to antibiotics fate.

There is already a significant body of work built around testing the effect of manure pit additives on manure nutrients, odor control, and greenhouse gas reduction. This research has led to a greater understanding of which products work and which do not, and the industry is better off for it. If a similar body of work develops around antibiotics fate, perhaps similar products will emerge to target residual antibiotics in animal waste. The current research and industry approach to this problem is focused on manure storage technologies such as anaerobic lagoons, fermentation, or compositing. However additive products are a similarly feasible solution and if certain bacterial species which are effective at degrading antibiotics residuals are brought to the market, perhaps focus will shift.

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Appendix A: Raw Data

Table A1: Raw data collected at time of sampling during the additive experiment.

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
			°C	°C	°C		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Coban 90	1	1	15.5	15.5	13.8	7.73	0.09	63400	21963	11350	29150	14681	
Coban 90	1	2	15.2	15.7	13.3	7.74	0.05	53400	25025	13819	22560	21141	81.2%
Coban 90	1	5	14.7	15.7	11.8	7.78	0.05	38200	38888	21563	20320	29484	
Coban 90	1	10	13.4	15.6	12.0	7.83	0.06	38600	39650	22125	23080	28188	
Coban 90	1	14	13.6	13.8	11.1	7.74	0.05	47200	64063	37400	23040		80.5%
Coban 90	1	21	16.2	16.2	11.2	7.97	0.04	42200	40363	22363	21680	27135	82.9%
Coban 90	1	32	15.1	15.1	11.6	7.99	0.05	56800	40108	22091	23520	30699	82.6%
Coban 90	1	40	15.3	17.6	12.3	8.23	0.05	49000	41089	22863	21800	27054	82.5%
Coban 90	2	1	15.3	14.4	15.9	7.93	0.06	59800	44713	25263	23520	20554	
Coban 90	2	2	14.9	16.0	14.0	7.63	0.06	69400	49988	29943	23960	18306	78.6%
Coban 90	2	5	14.1	16.0	12.2	7.76	0.06	53800	50813	28888	26480	20574	
Coban 90	2	10	13.3	15.2	12.4	7.78	0.06	38600	51288	29250	31240	25758	
Coban 90	2	14	13.2	14.1	11.2	7.85	0.05	62200	30575	17213	32160		83.4%
Coban 90	2	21	16.2	16.2	11.5	7.94	0.05	49600	53838	30763	83160	30942	82.1%
Coban 90	2	32	15.2	15.2	11.3	7.89	0.05	54200	54650	30875	33560	29484	81.9%
Coban 90	2	40	15.1	18	12.8	7.96	0.05	60600	55483	31399	33040	26487	81.6%
Control	1	1	15.7	15.8	13.7	7.72	0.05	51600	40500	22913	25850	28148	
Control	1	2	15.3	15.9	13.2	7.92	0.07	61600	39925	24086	20400	20250	80.1%
Control	1	5	14.2	15.9	11.3	7.87	0.05	34200	44238	27200	23240	24948	
Control	1	10	13.3	16.2	11.9	7.90	0.05	37800	38725	21413	24120	27621	
Control	1	14	13.7	14.0	10.9	7.89	0.05	40000	41000	17238	22160		82.6%
Control	1	21	17.0	17.0	8.8	7.96	0.04	49600	42675	23588	23000	27135	82.8%
Control	1	32	15.1	15.3	8.8	7.99	0.04	51800	45200	24628	24200	29484	82.7%
Control	1	40	15.5	18.3	12.6	8.16	0.04	48600	45214	24415	25640	26082	82.4%
Control	2	1	15.0	19.2	13.3	7.67	0.09	58000	41475	23700	26100	29363	
Control	2	2	14.6	15.4	12.9	7.67	0.06	62400	33588	18744	25040	23571	80.4%
Control	2	5	15.0	15.4	11.2	7.89	0.06	43800	40638	21525	24280	27472	
Control	2	10	12.5	15.2	11.3	7.90	0.06	45600	43438	24400	25720	25434	
Control	2	14	13.1	13.3	10.3	7.82	0.05	46400	44100	24975	27080		82.2%
Control	2	21	16.2	16.2	10.6	7.87	0.06	45800	44375	24550	22360	29646	82.5%
Control	2	32	14.3	14.7	10.7	7.97	0.05	43200	41189	22454	27200	30375	81.8%
Control	2	40	15	17.5	11.9	8.01	0.05	52600	50958	28359	30040	28666	81.9%
Manure Magic	1	1	15.7	15.9	14.3	7.68	0.06	60800	46388	25975	23550	21769	
Manure Magic	1	2	15.4	16.2	14.1	7.69	0.05	62400	34238	17939	28200	21060	80.3%

Table A1: Raw data collected at time of sampling during the additive experiment.

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Manure Magic	1	5	15.0	16.2	12.4	7.88	0.06	46800	47088	26663	25880	24948	
Manure Magic	1	10	13.7	16.1	12.4	7.87	0.05	59000	45088	25188	25680	24867	
Manure Magic	1	14	13.8	14.3	8.8	7.81	0.05	51200	24025	13100	29800		84.0%
Manure Magic	1	21	17.0	17.1	8.8	7.88	0.05	56000	47725	26550	31560	29565	82.3%
Manure Magic	1	32	14.7	14.9	11.5	7.9	0.04	46800	49860	27598	34640	28836	81.9%
Manure Magic	1	40	15.7	18	12.8	7.99	0.05	57800	54359	29861	33480	27378	81.7%
Manure Magic	2	1	15.6	15.6	14.0	7.68	0.07	53600	43963	25100	17450	27945	
Manure Magic	2	2	15.3	15.8	13.6	7.73	0.07	69400	37775	21323	26240	21384	79.9%
Manure Magic	2	5	15.0		11.9	7.87	0.05	49400	42838	23900	26080	27674	
Manure Magic	2	10	13.7	15.9	11.8	7.87	0.06	51600	43713	24375	24840	25758	
Manure Magic	2	14	13.4	14.0	11.0	7.86	0.05	49800	43763	24488	28200		82.3%
Manure Magic	2	21	16.1	16.2	11.4	7.84	0.05	49200	46175	26100	28440	26163	82.3%
Manure Magic	2	32	15.2	15.2	11.5	7.9	0.11	41600	46885	25543	27520	31833	82.3%
Manure Magic	2	40	15.3	18.2	12.5	7.97	0.04	50200	49229	26843	30760	25515	82.1%
MOC-7	1	1	16.5	17.2	15.5	8.14	0.08	79400	46450	26188	43700	13770	
MOC-7	1	2	16.3	17.6	15.2	8.22	0.04	75400	59700	34354	36320	20979	77.9%
MOC-7	1	5	15.2	17.6	13.1	7.76	0.04	67200	58838	32988	49440	24139	
MOC-7	1	10	14.3	16.3	13.6	8.05	0.04	62000	59913	33888	33160	29970	
MOC-7	1	14	14.1	16.3	11.9	7.81	0.06	56400	57888	32938	36800		80.8%
MOC-7	1	21	17.1	17.4	12.8	8.01	0.04	71800	58025	32275	48560	30132	80.4%
MOC-7	1	32	16	15.5	12.4	8.1	0.04	71000	60483	33274	44400	33939	80.8%
MOC-7	1	40	16	18.5	12.8	8.15	0.04	64800	63313	34196	49640	26811	80.7%
MOC-7	2	1	16.2	17.2	15.2	7.86	0.13	70200	54750	32800	41350	34087	
MOC-7	2	2	15.8	17.6	15.0	8.36	0.05	51200	51975	29938	38000	24381	78.5%
MOC-7	2	5	14.7	17.6	12.8	7.76	0.05	63200	64475	37563	38120	12231	
MOC-7	2	10	13.7		13.4	7.84	0.06	69600	63100	36338	39880	27297	
MOC-7	2	14	13.6	14.4	11.1	7.84	0.06	69000	54200	31000	44240		81.0%
MOC-7	2	21	16.1	17.1	12.5	7.93	0.03	53000	66200	37713	36840	36855	81.0%
MOC-7	2	32	15.7	16.1	11.7	8.1	0.05	70800	66946	37576	47760	31347	80.5%
MOC-7	2	40	15.1	18.5	13.4	8.09	0.04	59200	65260	36428	50400	31266	80.5%
More Than Manure	1	1	16.0	16.2	14.4	8.08	0.09	66400	48425	27863	41975	10631	
More Than Manure	1	2	15.5	16.6	14.4	8.22	0.09	67400	22838	12333	42240	20655	80.2%
More Than Manure	1	5	14.7	16.6	12.4	7.83	0.07	68400	64213	37500	49720	28431	
More Than Manure	1	10	13.8	16.4	13.0	8.00	0.13	71200	62625	36150	46360	29484	
More Than Manure	1	14	13.7	14.5	8.8	7.74	0.24	78800	65050	36986	42520		80.2%
More Than Manure	1	21	16.8	16.8	11.8	7.97	0.06	72000	64375	36725	42920	30537	80.7%
More Than Manure	1	32	14.5	15.1	11.6	8.02	0.06	63200	65815	37178	50880	33048	80.4%
More Than Manure	1	40	15.6	17.9	13.0	8.13	0.09	73600	67431	38163	47120	27540	80.5%

Table A1: Raw data collected at time of sampling during the additive experiment.

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
More Than Manure	2	1	17.5	17.8	12.8	7.81	0.04	72200	47575	27225	42750	23287	
More Than Manure	2	2	17.7	18.2	15.4	7.67	0.06	74400			16560	13736	
More Than Manure	2	5	16.5	18.2	13.1	7.72	0.06	67000	63650	37238	48480	22275	
More Than Manure	2	10	14.6	18.3	14.0	7.96	0.17	72000	64125	37163	47280	23976	
More Than Manure	2	14	15.3	16.0	12.2	7.91	0.05	75000	55288	31250	40560		81.0%
More Than Manure	2	21	17.9	18.0	13.2	7.99	0.06	69600	67675	38738	47760	28836	80.9%
More Than Manure	2	32	16.2	17	12.7	8.06	0.05	77600	67146	38040	47200	30375	80.4%
More Than Manure	2	40	16.7	18.6	13.6	8.13	0.04	72800	68574	38570	50920	32643	80.4%
Sludge Away	1	1	15.2	15.9	14.0	7.56	0.25	83000	33200	19450	43550	15188	
Sludge Away	1	2	14.9	15.9	13.8	8.05	0.17	81200	55263	32226	17680	10044	78.4%
Sludge Away	1	5	14.2		13.8	7.98	0.05	69400	62225	36513	40880	22032	
Sludge Away	1	10	13.5	15.5	12.7	7.81	0.06	61600	63050	36350	45920	24786	
Sludge Away	1	14	13.4	14.0	11.6	7.89	0.05	64800	57338	32125	38200		80.9%
Sludge Away	1	21	16.1	16.1	12.0	7.94	0.04	70000	64250	36550	46080	29484	80.7%
Sludge Away	1	32	13.9	14.5	11.9	7.95	0.05	65000	67449	38535	43840	29079	80.6%
Sludge Away	1	40	15.2	17	12.6	8.17	0.04	75400	66535	37258	47760	26568	80.6%
Sludge Away	2	1	15.2	16.3	14.1	7.72	0.04	70600	47825	28100	47100	49238	
Sludge Away	2	2	14.9	16.2	14.0	8.25	0.06	81800	55875	31833	35880	19116	77.9%
Sludge Away	2	5	14.3	17.0	12.1	7.68	0.07	67000	63588	37300	45120	23814	
Sludge Away	2	10	13.5	16.1	12.7	7.73	0.05	62600	61313	.	44920	26163	
Sludge Away	2	14	14.1	14.7	12.1	8.03	0.18	65400	54525	30525	42520		81.2%
Sludge Away	2	21	16.4	16.4	12.3	7.94	0.04	64200	62213	35713	48520	31509	80.1%
Sludge Away	2	32	14.3	15.3	11.8	8.04	0.04	69200	64185	36306	44240	36855	80.3%
Sludge Away	2	40	15.6	17.5	12.7	8.21	0.03	59600	69195	38764	52480	27702	80.4%
Sulfi-Doxx	1	1	15.7	16.2	14.5	8.14	0.06	82000	45388	25813	40200	30881	
Sulfi-Doxx	1	2	15.4	16.4	14.6	8.09	0.04	92400	47063	26439	44000	19116	78.3%
Sulfi-Doxx	1	5	14.5	16.4	12.9	7.90	0.07	59600	44863	25800	39160	21465	
Sulfi-Doxx	1	10	13.9	16.4	13.3	7.84	0.05	67000	61963	35513	44200	27540	
Sulfi-Doxx	1	14	13.8	14.7	12.1	8.07	0.05	69200	63888	36063	50640		80.5%
Sulfi-Doxx	1	21	16.3	16.4	12.7	8.01	0.04	67000	64563	36738	48360	30213	80.3%
Sulfi-Doxx	1	32	14.4	15.1	12.0	8.07	0.04	54000	66620	36921	39200	34344	81.0%
Sulfi-Doxx	1	40	15.5	17.6	12.9	8.19	0.04	74400	69696	38680	52480	31428	80.3%
Sulfi-Doxx	2	1	15.7	16.0	14.6	7.90	0.06	78600	52900	30825	42900	18938	
Sulfi-Doxx	2	2	15.4	16.5	14.4	8.07	0.1	85600	34038	19060	39600	19521	80.4%
Sulfi-Doxx	2	5	14.6	16.4	12.8	7.88	0.05	74000	66563	43650	42160	21789	
Sulfi-Doxx	2	10				7.93	0.04	63800	65575	37850	43520	25434	
Sulfi-Doxx	2	14	13.9	17.2	8.8	7.97	0.04	62600	62438	35438	44280		80.3%
Sulfi-Doxx	2	21	16.3	16.4	12.4	8.02	0.04	59200	65050	37038	47480	29241	80.6%

Table A1: Raw data collected at time of sampling during the additive experiment.

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Sulfi-Doxx	2	32	14.2	15	12.2	8.05	0.04	72200	66920	37514	54240	34425	80.4%
Sulfi-Doxx	2	40	15.5	17.5	12.8	8.19	0.04	70800	67381	37799	55640	27621	80.4%

Table A2: Nutrient content data processed in Ward Labs post conclusion of the additives experiment.

Additive	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
			ppm N	ppm N	ppm N	ppm N	ppm P2O5	ppm K2O	ppm S	ppm Ca	ppm Mg	ppm Na	ppm Zn	ppm Fe	ppm Mn	ppm Cu	ppm B	mmho/cm		%
Coban 90	1	1	1549.3	3499.2	1.9	5050.4	4433.8	3275.8	537.9	1214.7	1182	962.1	117.9	157.5	27.1	29.2	4.6	30.34	7.8	3.76
Coban 90	1	2	1885.1	3178.3	1.1	5064.5	4546	3157.8	544.2	1208.1	1152.5	964.8	120.1	160.4	27.5	29.2	4.5	30.57	7.8	3.79
Coban 90	1	5	1923.4	3090.6	1.1	5015.2	4563.6	3173.1	566.5	1222	1134.4	995.1	124	170.1	27.9	30.6	4.6	30.27	7.8	3.82
Coban 90	1	10	2602	2481.6	2.3	5086	4694.5	3526.6	609.5	1391.1	1254.5	1003.8	126.4	169.8	29	30.6	4.7	29.56	7.9	3.88
Coban 90	1	14	1992.4	3029	3	5032.5	4667.9	3655.9	565	1361.1	1298.1	1009.4	124.5	165.3	28.6	30.2	4.7	29.91	7.8	3.82
Coban 90	1	21	3056.8	2028.7	3.7	5089.1	4719.6	3612.2	590.6	1348.5	1227.7	1068.7	131.3	177.8	29.2	31.5	5	30.02	7.9	3.9
Coban 90	1	32	2227.4	2734.4	1.1	4962.9	4796.2	3771.9	597.6	1368.9	1314.8	1059.1	127.1	176.3	29.5	32.3	4.9	28.69	7.9	4.04
Coban 90	1	40	2594.1	2339.3	1.2	4934.6	4885	3838.4	598.8	1407.7	1360.6	1054.8	128	178.4	29.8	32.2	5	27.85	8	4.09
Coban 90	2	1	3377.3	2155.2	1.8	5534.3	6620.2	3602.5	681.9	1846.3	1855.8	1010.5	168	223.2	39.9	40.6	5.1	29.12	7.7	4.84
Coban 90	2	2	3629.3	2024	1.1	5654.4	6648.9	3588.8	694.2	1772.4	1870.2	986.6	170.4	238.6	39.3	39.6	4.9	29.21	7.7	4.91
Coban 90	2	5	3547.9	2132.3	4.2	5684.3	6628	3471	679.4	1739.1	1839.4	985.1	163.6	235.5	39.4	40.2	4.7	29.00	7.7	4.93
Coban 90	2	10	3251.4	2309.3	2	5562.7	6760.7	3478.6	731.8	1807.1	1819.7	999.6	171.7	231	39.5	41.3	5	28.72	7.8	4.99
Coban 90	2	14	3015.2	2240.1	1.8	5257.1	6798.3	3579.2	721.1	1798.3	1893.2	1013	168.3	231.1	40.3	41.1	5	28.09	7.7	5
Coban 90	2	21	2852.8	2639.8	2.2	5494.8	6789.7	3691.4	722.9	1866.6	1971.9	1008.7	168.3	227.4	40.8	41.8	5	28.07	7.8	4.97
Coban 90	2	32	4274.7	1469.6	2.6	5746.9	6897.9	3836.4	723.8	1924.5	1977.7	1057.1	173.7	233.9	41	41.7	5.5	27.79	7.8	5.14
Coban 90	2	40	3902.7	1635.4	1.4	5539.5	7284	3938.6	763.6	1996.9	2061.9	1109.4	181.9	246	44	44.7	5.5	29.96	7.9	5.26
Control	1	1	2181.1	2893	2.2	5076.3	4756.9	3489.7	568.9	1372	1334.5	940.3	126.1	164.3	29.9	31.5	4.5	28.13	7.8	4
Control	1	2	2194.6	3084.8	1.7	5281.1	4865.3	3541.3	578.8	1401.3	1345.7	971.6	129.2	171.7	30.9	32.1	4.6	31.8	7.8	4.02
Control	1	5	2249.2	2968	2.5	5219.7	4998	3497.8	627.7	1431.5	1337.1	981.5	135.9	187.7	31.4	32.9	4.7	31.28	7.7	4.07
Control	1	10	2446.3	2790.2	3	5239.5	4971.1	3537.9	617.5	1408.6	1350.9	967.2	134	177	31.1	32.7	4.6	30.47	7.8	4.07
Control	1	14	2484.8	2796.9	1.1	5282.8	5044.1	3551.4	618.4	1419	1359.5	991	135	189.8	32	33.2	4.5	30.82	7.8	4.14
Control	1	21	2396.1	2739.9	1.1	5137.1	5141	3626.3	640.7	1419	1391.1	1019.3	137.9	209.1	32.3	34	4.8	28.3	7.8	4.15
Control	1	32	2424.8	2765.8	1.1	5191.7	5510.3	3797.7	681.8	1585.7	1492	1057.9	149.7	215.4	35.5	36.7	5.1	28.53	7.9	4.41
Control	1	40	2455.6	2711.4	1.2	5168.2	5432.3	3916.1	686.6	1656.9	1552.3	1038.5	147.8	211.7	34.5	36.5	5	29.75	8	4.46
Control	2	1	2322.7	3136.9	1.2	5460.8	4976	3375.4	585.3	1414.5	1373	931.5	132.9	178.2	31.2	32.4	4.6	31.89	7.8	3.95
Control	2	2	2236.4	3029.1	1.2	5266.7	5157.5	3441.1	596.2	1481.2	1400.3	973.6	137.3	186.9	32.3	32.9	4.7	31.64	7.7	4.16
Control	2	5	2385.2	2912.3	1.2	5298.7	5190.9	3423.3	600.5	1486.2	1396.6	965	136.3	186.5	32.5	33.5	4.7	31.72	7.7	4.3
Control	2	10	2703.6	2785.9	1.2	5490.7	5436.8	3458.2	661.7	1514.4	1440.4	1004.1	143.1	201.5	34.1	35.2	4.6	29.96	7.7	4.31
Control	2	14	2200.7	3035.3	1.2	5237.2	5480.7	3533.9	626	1593.4	1482.8	992	143.8	196.1	34.2	35.1	4.8	31.51	7.8	4.34
Control	2	21	2302.1	2774.2	1.3	5077.5	5337	3554.9	638.2	1454.1	1431.2	1005.7	140	184.9	33.1	34.1	4.9	30.97	7.8	4.26
Control	2	32	2375	2741.8	1.3	5118.1	5542.8	3709	660.5	1522.2	1465	1064.5	148	213.8	34.2	36	5.1	30.16	7.8	4.34
Control	2	40	2600.2	2837.2	1.3	5438.7	6388.5	3925.1	807.3	1852.2	1721	1109.6	172.2	233.2	40.1	42.5	5.7	27.91	7.9	4.92
Manure Magic	1	1	3154.7	2524.7	1.3	5680.7	4118.3	2411.9	454.9	1080.9	1109.1	685	107.9	150.2	24.5	25.5	3.4	29.74	7.7	4.45
Manure Magic	1	2	3891.8	1730.8	1.2	5623.8	5331.4	3085.8	604	1413.6	1424.2	880.1	136.4	188.6	31.4	32.9	4.3	29.54	7.8	4.54
Manure Magic	1	5	3281.8	2291.6	1.2	5574.6	6040.1	3480.1	653	1606.3	1635.1	1005.8	151.6	211	36.4	37.3	4.8	29.56	7.7	4.56
Manure Magic	1	10	2160.2	3411.4	1.1	5572.7	5888.1	3546.9	677.2	1620.4	1633.4	998.3	151.2	207.3	35.5	37.2	4.8	29.05	7.7	4.54
Manure Magic	1	14	2469.6	3179.3	1.2	5650.1	5951	3441.3	667.7	1623.1	1596.7	988	153.1	213.4	35.8	37.3	4.8	29.07	7.8	4.44
Manure Magic	1	21	2527.2	3020.6	1.1	5548.9	6177.8	3690.2	674.4	1714.1	1700.1	1026.3	157.7	213.6	36.7	37.8	4.9	29.22	7.8	4.6

Table A2: Nutrient content data processed in Ward Labs post conclusion of the additives experiment.

Additive	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
Manure Magic	1	32	2540.1	3021.5	1.1	5562.7	6469.1	3723.7	718.2	1821.6	1775.8	1054.1	167.2	224.7	39	40.7	5.3	28.5	7.9	4.88
Manure Magic	1	40	3161.7	2519	1.1	5681.8	7029.7	3855.5	779.8	2034.7	1924.3	1098.1	173.8	244.7	42.5	45.5	5.4	27.49	7.9	5.26
Manure Magic	2	1	3340.7	2060.4	0.9	5402	5368.2	3471	654	1537.3	1496.6	968.4	137	186.1	32.7	34.4	4.6	29	7.7	4.29
Manure Magic	2	2	2610.9	2902.9	1	5514.8	5638.1	3488.1	644.8	1572.1	1528.1	979	143	191.6	33.7	34.6	4.9	28.8	7.7	4.31
Manure Magic	2	5	2784.4	2576.5	1	5361.9	5712	3600.4	631.9	1537.5	1546.5	1010.4	145.5	195.1	33.4	34.8	5	29.11	7.7	4.19
Manure Magic	2	10	2704.7	2663.7	1.2	5369.6	5584.8	3552.3	648.3	1511.2	1499.7	1015.3	142.5	190.3	33.4	34.7	4.9	28.95	7.7	4.23
Manure Magic	2	14	3129.3	2248.3	1.3	5378.9	5625.3	3540.6	646.6	1526.7	1535.8	999.8	141.7	190	32.9	34.9	4.8	28.95	7.7	4.29
Manure Magic	2	21	2569.9	2770.5	1.1	5341.5	5643.6	3692.8	659.1	1559.4	1564.7	1020	143.9	205.8	33.6	35.1	4.9	28.87	7.9	4.22
Manure Magic	2	32	2280.9	2972.6	1	5254.5	5843.1	3756.7	663.7	1686.9	1617.3	1042.7	149.2	201.5	35	36.4	5.1	28.5	7.8	4.48
Manure Magic	2	40	2353.6	3125.3	1.7	5480.6	6351.1	3829.7	733.9	1763.4	1726	1085.3	160.2	220	37.9	39.7	5.3	28.04	7.9	4.85
MOC-7	1	1	3545.4	2632.7	1	6179.1	8253.6	3579.2	801.9	2224.4	2461.9	959	209.8	269.5	52.7	51.4	5	27.44	7.7	5.72
MOC-7	1	2	3985.5	2147	1.1	6133.6	7909.5	3398.4	768.7	2046.6	2310.4	933.3	197.2	251.7	50	48.4	4.8	27.69	7.7	5.59
MOC-7	1	5	3841.5	2132.5	1	5975	8018.6	3468.8	751.7	2076.9	2343.2	952.2	196.5	258.2	51.1	48.7	4.8	26.83	7.7	5.67
MOC-7	1	10	3885.5	2347.3	1.1	6233.9	8410	3481.2	813.2	2215.9	2367.4	973.8	214.5	272.7	53	50.5	5.1	26.32	7.7	5.88
MOC-7	1	14	3639.6	2334.5	1	5975.1	8154.2	3503.6	790	2128.5	2356.3	959.5	200.5	263.8	51	49.4	4.9	26.49	7.7	5.73
MOC-7	1	21	4008.6	2250.4	1	6260	8582	3665.9	852.8	2340.9	2553.9	983.9	214.5	273.7	53.7	51.8	5.2	27.5	7.8	6.02
MOC-7	1	32	3677.5	2373	1	6051.5	6691.2	2851	643	1785.8	1950.2	774.3	165.8	217.7	41	40.4	4.1	26.44	7.9	6.03
MOC-7	1	40	3908	2402.7	1	6311.7	9036.5	3788.2	892.8	2376.3	2596.2	1047.6	224.9	297.7	55.7	55	5.4	26.04	7.9	6.19
MOC-7	2	1	3733.1	2587.7	1	6321.8	8084.1	3411.9	781.5	2183.1	2365.4	923.8	203	272.8	50.6	49.2	4.8	27	7.7	5.96
MOC-7	2	2	3973.1	2104.2	1.3	6078.6	8284.7	3438.5	824.8	2107.2	2364.8	952.2	208.3	268.9	51.5	50.2	5.1	26.01	7.8	5.96
MOC-7	2	5	4368.2	1920.6	1.1	6289.9	8466.2	3360.4	842.1	2187.1	2352	964.4	211.5	278.5	53.2	51.3	5	25.72	7.7	6.08
MOC-7	2	10	2141.8	4046.3	1.1	6189.2	8722.7	3558.3	843.8	2382.5	2477.9	992.1	217.6	283.7	55	53.1	5.1	27.14	7.7	6.2
MOC-7	2	14	2815.6	3404.6	1.3	6221.4	8624.9	3579.5	840.3	2266.1	2495.1	985.3	211.9	283.8	52.8	50.9	5.2	26.49	7.8	6.1
MOC-7	2	21	2836.7	3436.2	1	6274	8681.9	3522.6	842.2	2213.3	2418.2	996.6	214.8	282.5	53.8	52.4	5.2	25.98	7.7	6.25
MOC-7	2	32	3001	3370.1	1.6	6372.8	8996.2	3693.9	856.2	2479.9	2621.2	1025.2	222	302.3	56.8	54.8	5.3	26.13	7.8	6.52
MOC-7	2	40	3069.9	3156.8	1.4	6228	9593.9	4019.3	923.2	2597.4	2783.9	1124.2	239.4	325.3	60.1	58.1	5.8	25.46	7.9	6.46
More Than Manure	1	1	2555.2	3792.7	2.1	6350	8345.1	3341.5	807.7	2141.5	2315.2	955.5	205.3	278.9	50.8	48.9	5	27.09	7.8	5.95
More Than Manure	1	2	2463.5	3834.2	2.6	6300.3	8569.4	3408.9	817.5	2243.1	2396.7	957.2	207.3	282.5	51.6	49.5	5.1	27.44	7.7	6.03
More Than Manure	1	5	2818	3461.1	2	6281	8252.9	3369.4	781.5	2175.6	2353.8	936.4	195.1	276.3	49.8	49.2	4.8	27.28	7.7	6.03
More Than Manure	1	10	2916.4	3288.5	1.3	6206.2	8535.5	3425.8	819.7	2260.3	2400	981.5	210.6	284.5	52.3	51.1	5.1	27.71	7.7	6.15
More Than Manure	1	14	3767.3	2641.7	3.9	6412.9	8771.2	3534.4	861.3	2335.4	2484.9	1006.7	216.4	311.7	53.7	52.4	5.2	27	7.8	6.23
More Than Manure	1	21	2728	3412.9	3.4	6144.3	8935.3	3619.5	835.3	2337.6	2554.9	1013.2	218	293.6	53.6	52.2	5.4	27.35	7.7	6.17
More Than Manure	1	32	3332.1	3036	1.3	6369.4	9278.4	3728.8	875.6	2426.4	2657	1055.3	227.3	317.7	56.5	54.9	5.6	27.18	7.8	6.4
More Than Manure	1	40	3537.7	2738.6	1.4	6277.7	9432.9	3857.2	886.3	2461.2	2717.6	1077.6	223.5	320.2	57.1	55.7	5.5	26.72	7.9	6.51
More Than Manure	2	1	3169.2	3180.3	1.4	6350.9	7935	3296.5	735.6	2062.5	2267.1	918.7	186.3	258.8	47.5	47.4	4.7	27.27	7.7	5.92
More Than Manure	2	2	3580	2899.6	1.3	6480.9	8341.5	3425	796.1	2095.6	2400.1	953.5	199.7	281.5	49.8	49	4.9	27.49	7.8	6.04
More Than Manure	2	5	3113.2	3278.4	1.3	6392.9	8445.5	3459.8	783.5	2152	2393.2	975.2	205.4	280	50.5	49.8	5	27.59	7.6	6.01
More Than Manure	2	10	3289	3081.4	1.3	6371.7	8729.3	3525.2	827.5	2317.9	2504.9	987.8	214.5	296.1	52.2	51.6	5.1	27.46	7.6	6.15
More Than Manure	2	14	3164.7	3264.4	1.3	6430.4	8607.9	3616.9	823	2221.3	2477.6	1010.4	211.2	299.5	51.2	50.6	5.2	27.56	7.8	6.1

Table A2: Nutrient content data processed in Ward Labs post conclusion of the additives experiment.

Additive	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
More Than Manure	2	21	3220.3	3137.2	1.4	6358.9	9145.1	3700.1	899.2	2385.1	2616.6	1058.9	226.9	316.1	55.9	54.9	5.5	27.15	7.8	6.47
More Than Manure	2	32	3206.5	3198.9	1.3	6406.7	9364.2	3771.6	878.7	2434.5	2672.1	1081.7	229.8	330.7	56.6	56.2	5.7	27	7.8	6.5
More Than Manure	2	40	3222.8	3209.6	1.3	6433.7	10053.4	4057.3	978.8	2603.1	2860.9	1160.2	250.5	338.8	60.4	60.6	6.1	26.73	7.9	6.77
Sludge Away	1	1	2893.1	3531.9	1	6426	8497.4	3458.5	807.9	2205.1	2432.3	953.6	205.9	276.7	49.9	49.6	5	26.95	7.7	5.49
Sludge Away	1	2	2990.9	3464.8	2	6457.6	8638.4	3405.1	806.3	2156.7	2386.8	978.4	207.9	280.3	49.9	49.9	5.2	27.56	7.6	4.24
Sludge Away	1	5	3766.2	2758.5	1.1	6525.8	8746.9	3411.4	851	2295.3	2406.7	1000.6	210.7	287.3	51.6	51.4	5.3	26.94	7.8	5.96
Sludge Away	1	10	3153.5	3236.8	1	6391.2	8975.9	3475.5	843.3	2308.6	2468.3	1014.2	215.3	289.6	52.2	52.3	5.2	27.57	7.7	6.13
Sludge Away	1	14	3598.7	2755.8	1	6355.5	8630.3	3385.8	825.3	2273.2	2379.8	971.9	210.7	280.2	50	49.9	5.2	26.84	7.7	5.96
Sludge Away	1	21	3103.2	3046.9	1.1	6151.2	9159.7	3739	867.6	2392.6	2634.2	1043.4	219.8	297.6	53.7	53.3	5.5	27.18	7.7	6.2
Sludge Away	1	32	2918.7	3499.7	1	6419.4	9185.3	3775.4	860.4	2352.9	2619.1	1064.6	222.5	299.9	53.2	53.4	5.5	27.34	7.8	6.26
Sludge Away	1	40	3287.1	3154.1	1	6442.3	9184.4	3764.3	859.6	2557.6	2668.8	1028	213	296.6	53.2	54.1	5.3	26.77	7.8	6.53
Sludge Away	2	1	3132.8	3137.5	1.1	6271.5	8390.1	3483.4	807.5	2249.6	2393.1	968.1	205.4	277.2	49.9	49.5	5.1	27.42	7.7	5.98
Sludge Away	2	2	3413.6	2952.4	1.3	6367.2	8391.1	3397.6	790.2	2110.1	2346.9	968.9	200.4	272.4	48.8	49	5.1	27.4	7.7	5.9
Sludge Away	2	5	2947.4	3413.2	1.4	6361.9	8797.8	3541.1	869.7	2316.3	2470.7	995.2	217.9	292.2	51	51.2	5.2	27.2	7.8	6.1
Sludge Away	2	10	3675.8	2896.1	1.3	6573.2	8248.3	3514.8	797	2227.7	2403.8	940.2	206.6	266.9	54	51.4	4.9	27.73	7.7	6.03
Sludge Away	2	14	2932.7	3476.9	1.4	6411	8486.3	3562.4	844.8	2257.8	2470.6	962.6	212.1	269.4	54.3	51.7	5.1	27.56	7.7	6.09
Sludge Away	2	21	3347.1	3118.5	1.8	6467.3	8715.3	3541.8	873.1	2251	2462.6	979.2	220.8	277.6	55.1	53.5	5.3	27.04	7.7	6.2
Sludge Away	2	32	3588.4	2897.1	2	6487.5	8941.9	3690.5	864.5	2396.7	2624.7	984.5	223.1	283.4	56	54.6	5.4	27.13	7.8	6.37
Sludge Away	2	40	3780.2	2736.8	1	6518	9543.3	3938	969	2645.4	2768.8	1064.1	244	315	61.2	60.9	5.7	26.69	7.9	6.71
Sulfi-Doxx	1	1	2954.6	3419.1	1.3	6375	8754.4	3443.7	815.4	2185	2501.1	992.4	211.4	294.1	51.9	51.1	5	27.29	7.7	6.09
Sulfi-Doxx	1	2	3787.5	2670.3	1.3	6459	8757.9	3337	805.8	2238.5	2465.7	954.3	211.6	286.8	51.9	50.9	5	27.28	7.7	6.15
Sulfi-Doxx	1	5	4242.7	2190.4	1.3	6434.4	9154.8	3471.2	844.2	2280.4	2549.3	1000.6	218.4	309.2	54.4	52.5	5	27.41	7.7	6.17
Sulfi-Doxx	1	10	3204.3	3285.9	1.3	6491.4	9130.8	3468.5	852.4	2385.5	2565.5	984.3	221.5	296.8	54.6	52.8	5.2	27.46	7.7	6.34
Sulfi-Doxx	1	14	2720.4	3639.7	1.3	6361.4	9097.6	3565.6	845.6	2408.3	2612.6	988.8	219.2	298.1	54.3	53.5	5.3	27.37	7.7	6.22
Sulfi-Doxx	1	21	3429.3	3076.4	1.4	6507.1	9160.4	3566.1	847.1	2409.9	2633.2	1004.3	222.1	300.6	54.7	53.3	5.5	27.2	7.8	6.4
Sulfi-Doxx	1	32	3300	3244.6	1.4	6546	9823.4	3794.4	896.1	2500.9	2808.9	1072.1	235.3	326.3	57.9	55.7	5.9	26.72	7.8	6.47
Sulfi-Doxx	1	40	3562.7	2888.1	1.3	6452.1	9310	3655.4	907.8	2493.3	2720.6	1028.1	224.9	309.7	55.5	55.3	5.5	26.55	7.9	6.82
Sulfi-Doxx	2	1	3262.8	3311.5	1.4	6575.7	8985.1	3436.7	825.7	2271.6	2547	994.1	214.2	294.8	52.2	52.1	5.1	27.46	7.6	6.29
Sulfi-Doxx	2	2	3411.9	3092	1.3	6505.2	8705.5	3401.4	791.4	2149.4	2492.8	970.3	204.2	279	50.4	49.7	4.9	27.59	7.6	6.22
Sulfi-Doxx	2	5	3626.6	2771.8	1.5	6399.9	9091.1	3513.3	848.6	2293.5	2566.7	1008	217.8	299.4	53.3	52.9	5	27.49	7.6	6.3
Sulfi-Doxx	2	10	3457.5	3080.2	1.3	6539	9267.9	3540.7	873.8	2356.4	2602.1	1028.8	221.8		54.1	55	5.2	27.47	7.7	6.35
Sulfi-Doxx	2	14	3990	2403.9	1.3	6395.2	9018.1	3551	853.6	2285.3	2586.2	1012	214.6	303.1	52.6	52.9	5.2	27.23	7.8	6.28
Sulfi-Doxx	2	21	3186.9	3187.3	1.4	6375.6	9370.7	3582	878.9	2381.8	2632.4	1033.3	223.2	318.3	55.4	55.5	5.4	27.46	7.8	6.4
Sulfi-Doxx	2	32	3246.9	3067.5	1.4	6315.7	9796.5	3761.7	897.2	2517.6	2780.6	1088.8	232.9	330.2	58.2	57.2	5.6	27.02	7.8	6.62
Sulfi-Doxx	2	40	3061.4	3272	1.5	6335	9973.9	3956.7	942.6	2602.1	2876.1	1119.6	239.8	337.9	58.1	59.4	5.8	26.81	7.9	6.66

Table A3: Antibiotics concentrations reported from the additives experiment

Disinfectant	Reactor (1or2)	Days Post Dosing	Chlortetracycline	Lincomycin	Tiamulin	% Oleandomycin
			ng/g	ng/g	ng/g	%
none	Composite	0	9879	111.31	370.51	
Coban 90	1	1	4035	65.99	119.80	163.0
Coban 90	1	5	5778.7	422.3	187.8	77.2
Coban 90	1	14	6433.2	413.3	111.3	93.0
Coban 90	1	21	5672.2	487.4	65.0	98.0
Coban 90	1	40	6924.5	207.8	146.3	90.1
Coban 90	2	1	12363	68.10	199.59	159.6
Coban 90	2	5	17848.9	572.5	419.8	70.9
Coban 90	2	14	6126.2	50.9	124.3	90.6
Coban 90	2	21	14526.3	963.0	554.4	97.5
Control	2	40	8136.5	120.7	231.0	93.8
Control	1	1	4945	114.26	109.41	175.0
Control	1	5	6701.6	31.2	295.9	94.8
Control	1	14	2998.2	20.9	102.4	90.9
Control	1	21	1413.5	37.2	50.2	100.1
Control	1	40	8755.9	301.1	207.1	88.5
Control	2	1	3347	47.11	200.21	174.5
Control	2	5	5242.0	163.7	247.5	85.4
Control	2	14	5425.8	95.4	101.7	92.3
Control	2	21	9420.9	97.2	73.2	97.9
Control	2	40	10610.7	106.9	504.2	101.4
Manure Magic	1	1	6010	111.31	211.40	174.9
Manure Magic	1	5	6188.9	74.5	344.7	74.0
Manure Magic	1	14	11387.0	120.2	97.2	92.2
Manure Magic	1	21	5008.6	57.5	92.8	102.8
Manure Magic	1	40	8750.0	174.4	227.9	88.0
Manure Magic	2	1	5068	78.37	97.42	168.6
Manure Magic	2	5	10451.2	463.4	286.7	97.2
Manure Magic	2	14	5254.0	82.0	95.8	93.0
Manure Magic	2	21	10385.4	273.0	80.9	101.7
Manure Magic	2	40	5862.8	44.8	257.4	89.0
MOC-7	1	1	17242	60.89	336.39	165.8
MOC-7	1	5	12415.5	50.2	199.9	78.5
MOC-7	1	14	12427.3	34.0	199.2	90.3
MOC-7	1	21	12391.3	384.9	136.2	94.5
MOC-7	1	40	21553.0	330.0	733.7	94.5
MOC-7	2	1	19297	184.66	422.93	166.0
MOC-7	2	5	17612.0	52.1	224.6	84.9
MOC-7	2	14	16350.7	76.0	80.4	97.1
MOC-7	2	21	8076.8	71.6	70.4	96.9
MOC-7	2	40	22903.9	104.4	954.7	96.6
More Than Manure	1	1	9363	127.13	276.49	175.0
More Than Manure	1	5	16485.0	40.8	326.5	96.4

More Than Manure	1	14	19437.3	295.0	83.3	88.0
More Than Manure	1	21	11259.5	484.8	213.7	92.3
More Than Manure	1	40	22806.9	363.1	781.6	103.5
More Than Manure	2	1	23260	185.13	338.28	163.3
More Than Manure	2	5	13191.8	49.8	263.3	83.2
More Than Manure	2	14	14040.8	101.3	91.5	92.4
More Than Manure	2	21	13131.2	160.3	103.1	96.3
More Than Manure	2	40	21561.5	121.7	602.5	100.5
Sludge Away	1	1	7048	73.99	213.53	156.1
Sludge Away	1	5	18094.9	90.1	199.8	68.4
Sludge Away	1	14	8517.6	29.0	97.2	90.3
Sludge Away	1	21	13313.1	170.5	142.7	95.1
Sludge Away	1	40	18019.7	114.4	467.4	98.1
Sludge Away	2	1	19240	120.88	473.25	158.8
Sludge Away	2	5	18338.5	296.2	334.4	85.4
Sludge Away	2	14	18085.5	155.2	69.5	91.2
Sludge Away	2	21	5774.5	24.7	125.3	97.1
Sludge Away	2	40	23428.1	253.9	659.7	90.5
Sulfi-Doxx	1	1	16235	113.04	394.59	127.5
Sulfi-Doxx	1	5	19008.3	71.0	116.7	68.0
Sulfi-Doxx	1	14	20719.0	244.5	73.7	92.6
Sulfi-Doxx	1	21	13440.3	116.5	117.9	100.2
Sulfi-Doxx	1	40	22455.3	76.3	584.3	91.7
Sulfi-Doxx	2	1	25455	299.99	496.52	158.3
Sulfi-Doxx	2	5	13156.5	24.2	110.4	60.7
Sulfi-Doxx	2	14	12841.6	105.8	56.7	95.3
Sulfi-Doxx	2	21	13652.3	100.6	98.4	99.1
Sulfi-Doxx	2	40	20802.8	133.6	611.9	92.4

Table A4: Disinfectant Data Collected at time of sampling

Disinfectant	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
			°C	°C	°C		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Chlorine Bleach	1	1	17.0	17.6	12.8	7.63	0.06	113800	83138.75	54121.25	58350	33918.75	
Chlorine Bleach	1	2	17.3	17.9	16.4	7.80	0.06	79600	79453.75	51190	60900	26527.5	79%
Chlorine Bleach	1	3	17.7	18.9	15.8	7.57	0.04	96000	82682.5	53682.5	52550	28046.25	80%
Chlorine Bleach	1	10	17.4	18.7	12.8	7.89	0.09	85600	83975	53440	50950	24240	80%
Chlorine Bleach	1	14	17.2	18.4	12.8	7.89	0.08	86600	80082.5	51293.75	69800	28078	79%
Chlorine Bleach	1	21	15.5	16.7	13.5	7.74	0.07	77600	80521.25	51340	58000	21100	79%
Chlorine Bleach	1	32	16.7	21.1	14.4	7.53	0.1	82600	80156.25	49443.75	53800	18933.75	79%
Chlorine Bleach	1	40	18.3	19.3	15.2	7.97	0.04	79200	81850	50870	70050	26260	78%
Chlorine Bleach	2	1	15.9	17.4	15.5	7.60	0.07	94800	80635	51412.5	59450	38475	
Chlorine Bleach	2	2	17.0	18.0	16.1	9.37	0.03	83800	79697.5	51658.75	55600	25413.75	79%
Chlorine Bleach	2	3	18.7	19.3	12.8	7.51	0.06	99000	80842.5	51966.25	71750	29058.75	79%
Chlorine Bleach	2	10	17.6	19.1	12.8	7.57	0.11	85600	78925	50375	55800	21210	79%
Chlorine Bleach	2	14	17.5	20.3	12.8	7.59	0.05	73400	82611.25	53051.25	48850	20402	79%
Chlorine Bleach	2	21	16.4	17.9	12.8	7.44	0.07	81800	77873.75	49208.75	63300	19000	79%
Chlorine Bleach	2	32	16.8	21.4	14.4	7.53	0.04	113800	80705	49711.25	56850	21262.5	79%
Chlorine Bleach	2	40	18.8	21.4	12.8	7.73	0.02	83400	81340	49746.25	67100	27068	79%
Control	1	1	15.5	16.7	14.2	7.44	0.08	78800	81396	52889	52950	29970	
Control	1	2	18.5	15.9	14.4	7.83	0.07	84600	78264	50775	70950	29565	79%
Control	1	3	15.2	16.3	13.7	7.53	0.04	87200	80986	52405	64050	29970	79%
Control	1	10	15.7	17.2	15.4	8.10	0.07	83600	80808	52459	56250	24139	79%
Control	1	14	15.6	16.0	14.2	7.76	0.06	73200	80354	51753	66650	22725	79%
Control	1	21	13.9	15.2	12.9	7.64	0.06	97200	78280	50096	52000	18600	79%
Control	1	32	15.3	20.0	13.7	8.66	0.06	83200	81344	50768	58550	25515	79%
Control	1	40	16.6	17.7	14.2	7.78	0.04	98800	81270	49791	78350	33431	78%
Control	2	1	15.0	15.6	14.6	7.44	0.09	86600	83506	55089	66400	32602.5	
Control	2	2	15.6	16.4	15.4	7.83	0.11	84400	82641	54403	60850	30931.25	79%
Control	2	3	15.7	16.2	14.8	7.53	0.03	105000	80269	52396	60400	28046.25	78%
Control	2	10	14.8	17.3	14.6	8.10	0.07	90000	83989	54991	67200	22119	79%
Control	2	14	15.1	15.5	13.7	7.76	0.07	63200	81639	52870	55300	20200	79%
Control	2	21	12.7	15.1	12.0	7.64	0.05	85600	83548	53880	59150	23750	79%
Control	2	32	15.2	20.5	13.3	8.66	0.04	78800	84788	52855	57950	24806.25	79%
Control	2	40	16.4	17.8	13.4	7.78	0.04	87200	83970	52033	64650	32421	78%
Pi-Quat	1	1	15.3	17.1	15.2	7.46	0.04	83000	83303	54515	61950	29463.75	
Pi-Quat	1	2	17.1	17.2	15.5	7.38	0.03	55800	80040	52053	80250	31185	79%
Pi-Quat	1	3	1.9	17.9	12.8	7.40	0.07	97000	82718	54471	70750	31893.75	79%
Pi-Quat	1	10	16.7	18.4	15.2	7.40	0.08	103200	83725	54991	61750	18483	79%

Table A4: Disinfectant Data Collected at time of sampling

Disinfectant	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Pi-Quat	1	14	16.6	17.0	14.7	7.55	0.08	94000	83220	54675	58400	16766	79%
Pi-Quat	1	21	13.9	16.3	13.4	7.61	0.05	104000	78590	51404	61750	20500	78%
Pi-Quat	1	32	16.3	21.7	13.5	7.44	0.06	53600	86443	56103	83950	27540	79%
Pi-Quat	1	40	18.3	19.2	14.4	7.47	0.04	105600	88200	57170	71250	26866	78%
Pi-Quat	2	1	15.7	16.3	15.2	7.35	0.06	91600	88539	58728	71700	32602.5	
Pi-Quat	2	2	16.0	16.3	15.0	7.43	0.06	103200	79540	52324	67000	27540	79%
Pi-Quat	2	3	17.9	17.9	14.2	7.49	0.06	91600	81093	53381	69050	28957.5	79%
Pi-Quat	2	10	15.5	19.0	14.5	7.36	0.06	94400	83388	54800	52250	22119	79%
Pi-Quat	2	14	16.0	16.3	14.1	7.33	0.08	85800	81139	52941	73900	20538	79%
Pi-Quat	2	21	13.2	16.6	13.0	7.64	0.07	90600	82763	54369	64100	21300	79%
Pi-Quat	2	32	16.1	22.3	13.3	7.70	0.07	83000	86353	56295	80100	23591.25	79%
Pi-Quat	2	40	18.9	20.4	14.0	7.51	0.05	92200	87768	56780	70450	26260	78%
Tek Trol	1	1	15.1	16.7	14.7	7.37	0.14	60400	84213	55319	71450	35336.25	
Tek Trol	1	2	16.5	16.8	12.8	7.50	0.03	85200	81858	53856	57050	27641.25	79%
Tek Trol	1	3	16.8	16.8	15.3	7.81	0.05	97800	81451	53244	61750	30678.75	79%
Tek Trol	1	10	16.3	17.6	12.8	7.87	0.06	91200	85680	56375	65250	25553	79%
Tek Trol	1	14	16.1	16.4	14.2	7.47	0.07	75200	84590	55970	60100	23310	79%
Tek Trol	1	21	13.1	15.6	12.8	7.60	0.07	96200	81849	53325	61000	19200	79%
Tek Trol	1	32	16	21.2	13.3	7.58	0.07	91600	86066	55850	65550	30577.5	78%
Tek Trol	1	40	18.6	19.0	12.8	7.76	0.04	97800	88344	57269	77550	27876	78%
Tek Trol	2	1	15.7	16.0	14.2	7.38	0.07	83200	82825	54465	59750	32906.25	
Tek Trol	2	2	15.9	16.0	14.4	7.51	0.04	61000	84040	55650	55800	29666.25	79%
Tek Trol	2	3	15.7	16.1	14.8	7.96	0.05	104400	83155	54934	67200	33007.5	79%
Tek Trol	2	10	15.0	17.4	14.3	7.51	0.04	86800	81710	53430	68100	25856	79%
Tek Trol	2	14	15.4	15.7	13.8	7.43	0.10	82800	87423	57956	59350	23432	79%
Tek Trol	2	21	11.9	15.2	11.8	7.45	0.08	101800	84676	55378	58000	21400	79%
Tek Trol	2	32	15.5	20.6	13.0	7.50	0.08	60400	90921	59804	85250	31590	78%
Tek Trol	2	40	17	17.9	13.0	7.52	0.05	103400	82145	52195	79250	31209	78%
Virkon	1	1	15.7	16.4	15.6	8.08	0.04	61600	77110	48680	46600	25110	
Virkon	1	2	16.2	16.8	15.6	8.14	0.05	102000	79916	51776	56050	24907.5	79%
Virkon	1	3	16.3	16.6	15.0	7.61	0.04	95800	79803	51678	62000	31691.25	79%
Virkon	1	10	16.2	18.0	15.6	7.69	0.07	72800	78183	49831	55600	18180	80%
Virkon	1	14	16.0	16.0	14.6	8.00	0.08	83600	79304	50815	66700	22932	79%
Virkon	1	21	14.3	15.9	13.2	7.69	0.09	90000	79373	50530	68300	20750	79%
Virkon	1	32	16	20.3	14.1	7.74	0.05	94800	79460	49118	52300	23186.25	79%
Virkon	1	40	17.6	18.1	14.4	7.91	0.02	91600	82574	50541	52000	23688	79%
Virkon	2	1	16.1	16.5	12.6	7.43	0.13	53600	79584	50620	29350	22983.75	
Virkon	2	2	16.1	16.8	15.6	7.78	0.02	78800	78120	50090	56100	26932.5	79%

Table A4: Disinfectant Data Collected at time of sampling

Disinfectant	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Virkon	2	3	16.5	17.7	15.0	7.78	0.03	83600	78996	50569	67300	31691.25	79%
Virkon	2	10	16.3	18.0	15.8	7.89	0.04	87200	81468	52158	53650	14342	79%
Virkon	2	14	16.3	17.8	15.0	7.75	0.06	72600	83386	52759	49650	25326	80%
Virkon	2	21	16.1	16.5	13.2	7.60	0.05	100400	79409	49714	61300	28000	79%
Virkon	2	32	16.1	21.2	14.1	7.87	0.04	61600	80956	49785	58100	24806.25	79%
Virkon	2	40	17.1	18.9	17.6	7.83	0.02	102000	80831	49493	59100	26563	78%

Table A5: Nutrient content data processed post disinfectant experiment.

Disinfectant	Replication	Days Post Dosing	Org. N	NH3-N	Nit. N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
			ppm N	ppm N	ppm N	ppm N	ppm P2O5	ppm K2O	ppm S	ppm Ca	ppm Mg	ppm Na	ppm Zn	ppm Fe	ppm Mn	ppm Cu	ppm B	mmho/cm		%
Chlorine Bleach	1	1	3991.1	2951.6	2.2	6945	9189.2	3671.7	774.6	2385.9	2299.5	1079.6	214.7	265.9	56.1	47.4	3.9	26.45	7.6	7.61
Chlorine Bleach	1	2	4685.1	2357.2	0.7	7043	9099.4	3650.9	778.6	2374.2	2279.4	1083.2	215.6	265.6	55.4	46.8	3.9	25.84	7.6	7.49
Chlorine Bleach	1	3	5322.2	1822.8	1.9	7147	9269.5	3667.2	772.8	2421.2	2377.1	1087.6	215.9	270.7	56.3	47.9	3.9	26.46	7.6	7.54
Chlorine Bleach	1	10	2891.1	4071.8	1.2	6964	9468	3718.5	790	2472.9	2489.7	1098.3	223	272.2	56.7	48	3.3	25.35	7.7	7.56
Chlorine Bleach	1	14	3034	4235.6	1.3	7271	9482.6	3778.7	792.2	2497.6	2452.1	1115.6	221.3	276.8	57.8	48.6	4	27.08	7.6	7.66
Chlorine Bleach	1	21	3016.2	4382.7	1.1	7400	10307.8	4004.5	890.6	2821	2738.2	1193.5	243.1	293.2	62.5	53	3.5	24.51	7.5	8.02
Chlorine Bleach	1	32	2885.8	4390	1.1	7276.9	10170.4	4023	844.7	2677.1	2539.5	1175.7	234.2	285	61.0	51.6	4.5	27.58	7.7	7.87
Chlorine Bleach	1	40	3241	4404.1	1	7646.1	10774.1	4256	931.5	2897.9	2712.9	1254.7	255.7	313.6	66.1	56.2	4.5	26.64	7.6	8.26
Chlorine Bleach	2	1	3315.7	3959.2	1.2	7276.1	9398.1	3673.6	792.8	2481.9	2456.6	1091.8	219.3	268.8	56.6	47.7	3.1	27.04	7.6	7.5
Chlorine Bleach	2	2	3799.5	3346.2	0.9	7146.6	9405.6	3704.2	781.1	2488.9	2439	1094.6	219.4	267.5	56.6	48.7	3.4	27.1	7.6	7.47
Chlorine Bleach	2	3	4001.4	3395.3	0.7	7397.4	9363.4	3684.5	829.7	2506.7	2330.6	1089.1	222.1	260.8	57.5	49.9	3.9	26.3	7.7	7.79
Chlorine Bleach	2	10	4381.7	2811.2	0.2	7193.1	9613.8	3846	805.6	2579.9	2464	1142.9	224.7	284.4	58.8	49.3	3.9	26.86	7.6	7.52
Chlorine Bleach	2	14	3311.9	4004.2	0.9	7317	9806.3	3891.4	851.4	2651	2552.1	1113.7	230.7	293.5	59.4	50.5	3.7	26.04	7.5	7.79
Chlorine Bleach	2	21	4376.4	2935.2	2.4	7314	10031.4	3943	855.4	2755.7	2522.4	1164.7	237.5	277.5	61.4	52.7	4.4	26.63	7.5	7.94
Chlorine Bleach	2	32	3603.4	3924.5	2.0	7529.9	10394.2	4128.7	881.8	2801.9	2647.5	1222	241.9	306.1	63.4	53.6	4.3	26.97	7.6	7.9
Chlorine Bleach	2	40	3918.4	3576.3	2.2	7496.9	10702.6	4282.1	911.2	2837.3	2703.3	1261.9	250.5	301	64.8	55.2	4.8	26.74	7.7	8.17
Control	1	1	3716.9	3658.7	3.4	7379	9166.5	3625.8	779.5	2347.4	2231.6	946.8	213.4	257.7	55.8	47.4	4	26.38	7.7	7.56
Control	1	2	3245	3934.7	1.2	7181	9296.7	3674.2	787.7	2576.9	2369.2	970.3	215.8	273.7	56.4	47.5	3.6	27.08	7.6	7.5
Control	1	3	3730.6	3564.4	1.6	7296.6	9513	3772.6	836.9	2472.9	2299.9	973.6	221.3	269.4	57.9	49.9	4.3	25.86	7.6	7.77
Control	1	10	3470.2	3735.1	1.1	7206.4	9643.7	3809	852.2	2533.9	2447.6	1003.2	229.5	285.6	58.0	49.9	3.9	26.5	7.7	7.63
Control	1	14	3517.8	3729.5	0.9	7248.2	9730.9	3787.7	830.8	2622.6	2555.4	999.8	227.1	298.7	58.6	50	3.8	26.18	7.6	7.67
Control	1	21	3610.5	3707.1	2.5	7320.1	9629.7	3846.7	810.8	2508.2	2337.2	1001.4	225	271.4	58.1	49.6	4.6	25.93	7.6	7.77
Control	1	32	5406.4	2365.3	12	7783.8	10136.8	4012	862.7	2712.9	2460.8	1049.1	236.9	289.9	61.4	52.2	4.6	26.5	7.6	7.94
Control	1	40	4375.7	3278	2	7655.7	11096.5	4312.7	973.3	2983.6	2794.9	1129.5	261	326.8	66.9	57.2	4.8	26.97	7.7	8.28
Control	2	1	3895.2	3264.3	1.4	7160.9	9331.4	3695.8	776.3	2415.2	2178.3	952.9	210.8	273.5	56.7	47.7	4.3	26.44	7.6	7.8
Control	2	2	3698.8	3471.4	1.2	7171.4	9411.5	3675.3	789.2	2469.6	2350.9	968.1	219.6	289.8	56.7	47.9	4	26.34	7.6	7.73
Control	2	3	4954.6	2354.1	7.4	7316.1	9509.1	3703.2	822.1	2480.4	2239.5	961.6	217.4	274.4	57.5	48.9	4.3	26.05	7.6	7.97
Control	2	10	3831.1	3354.1	2	7187.2	9579.8	3692.1	794.6	2448.9	2386.7	974.9	219.5	266.2	56.9	47.4	3.9	26.38	7.6	7.79
Control	2	14	4023.1	3042	7.1	7072.2	9806.5	3799.5	805.6	2598.8	2503.4	1008.8	228.1	288.3	59.2	49.4	4	26.57	7.5	7.81
Control	2	21	3858.6	3392.5	3.8	7254.9	10240.3	3877.9	875.4	2784.5	2589.4	1021.7	236	300	61.8	52.3	3.9	25.37	7.5	8.22
Control	2	32	3983.5	3362.6	3.4	7365.8	10499	4157.2	870.9	2736.4	2467	1072.9	236	291.6	63.5	53.2	4.9	25.9	7.6	8.15
Control	2	40	3586.7	3954.9	3	7544.5	11228.8	4359.9	989.4	3053.2	2643.9	1135.9	258.3	318.5	68.7	58.1	5.2	25.86	7.6	8.7
Pi-Quat	1	1	3561.9	3529.3	2.8	7094	9424.1	3708.7	795.6	2496.9	2462.1	976.7	220.6	283.3	56.8	49.1	3.7	26.41	7.6	7.77
Pi-Quat	1	2	4297.2	3101.5	2.3	7401	9492.2	3687.6	799.5	2535.6	2533	974.2	227.3	310.8	57	47.3	3.2	26.03	7.6	7.69
Pi-Quat	1	3	3675.2	3555.1	3.7	7234	9081.8	3615	773.9	2378.1	2241.9	947.1	213.9	256.8	55.2	46.8	4.1	26.25	7.6	7.85

Table A5: Nutrient content data processed post disinfectant experiment.

Disinfectant	Replication	Days Post Dosing	Org. N	NH3-N	Nit. N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
Pi-Quat	1	10	3611.7	3250.6	2.7	6865	9568.3	3702.2	807.6	2524.2	2492.2	986.5	222.5	288.8	56.7	48.3	3.8	26.46	7.6	7.86
Pi-Quat	1	14	4238.2	2796	3.8	7038	9697.6	3763.7	787.3	2551.1	2522.9	985.5	226.4	281	57.7	49	3.5	26.27	7.6	7.93
Pi-Quat	1	21	4627.9	2679.4	2.7	7310	9646.4	3852	795.4	2560.2	2456.1	1016.3	226.7	291	58.7	49.9	4.1	25.25	7.6	8.13
Pi-Quat	1	32	3829.2	3341.5	4.3	7175	10131.2	4103	829	2678.3	2329.1	1073.9	229.6	287.1	61.9	53.1	4.7	24.2	7.6	8.45
Pi-Quat	1	40	3606.7	3150	4.3	6761	10443.6	4125.1	859.4	2718.2	2504.4	1085.3	241.6	297	62.5	52.9	4.7	23.74	7.6	8.81
Pi-Quat	2	1	3646.8	3440.8	2.3	7090	9289.1	3741.9	784.8	2479	2400	1005.9	216.3	284.6	56	47.6	3.8	25.95	7.6	7.57
Pi-Quat	2	2	4361.3	3029.4	2.3	7393	9145.1	3700	784.8	2421.6	2302.6	971.1	215.3	281.8	55.6	46.8	3.8	26.34	7.6	7.54
Pi-Quat	2	3	3664.1	3803.8	3.1	7471	9276.3	3765.8	791.2	2476.5	2272.9	976.2	215.5	262.1	56.5	47.9	4.4	26.79	7.6	7.67
Pi-Quat	2	10	3187.1	3714	2.9	6904	9344.5	3728.3	793	2486.9	2399.4	978.8	220.3	278.5	55.8	47.1	3.8	27.02	7.6	7.82
Pi-Quat	2	14	2828.8	4333	1.2	7163	9367.5	3786	783.2	2581.2	2421.5	990.6	217.9	276.2	56.8	48.6	3.9	26.29	7.6	7.78
Pi-Quat	2	21	3010.8	4131.4	1.8	7144	9459.8	3869.6	786	2495.4	2325.3	999.6	221.9	273.1	57.8	48.9	4.3	25.76	7.6	8.03
Pi-Quat	2	32	3189.3	3822.9	1.9	7014	10298	4022.4	862.2	2804.1	2777.6	1077.6	244.5	327	61.2	52.1	3.2	24.84	7.6	8.42
Pi-Quat	2	40	3566.9	3411.6	1.5	6980	10655.2	4319	879.8	2809.9	2634.7	1128.5	251.7	306.7	65	55	4.6	23.5	7.6	8.76
Tek Trol	1	1	3379.5	3699.7	1.9	7081.1	9176	3715.6	802.8	2412.3	2271.8	1006.8	215.4	254.6	55.5	46.8	4.1	26.27	7.7	7.85
Tek Trol	1	2	3973.2	2895.6	1.3	6870.1	9229.1	3756.3	816.8	2427	2420.1	1027.3	219	273.2	56.2	47.8	3.4	26.09	7.8	7.78
Tek Trol	1	3	3565.7	3290.9	1.1	6857.7	9285.7	3773.9	817	2448.8	2468.4	1030.9	218.1	270.8	56.4	47.5	3.2	26.64	7.7	7.83
Tek Trol	1	10	3835.4	3124	2.5	6961.9	9236.5	3840.9	798.2	2451.7	2193.1	1032.8	210.8	257.5	56.9	48.6	4.3	25.92	7.7	7.89
Tek Trol	1	14	4020.4	2934.9	2.4	6957.7	9382.4	3777.8	801.8	2457.9	2332.1	1029.9	216.3	280.9	56.5	47.9	4	25.76	7.7	7.95
Tek Trol	1	21	4527.1	2520.3	2.5	7049.9	9772.1	3902.2	847.4	2631.1	2536	1097.5	227.7	294	58.6	50.2	3.7	25.83	7.6	8.17
Tek Trol	1	32	3415.7	3607.3	2.6	7025.6	10652.9	4168.3	923.4	2854.4	2948.2	1149.4	251.7	322.4	63	52.8	6.3	24.51	7.6	8.46
Tek Trol	1	40	3347.9	3652.3	2.2	7002.4	10748.4	4343.5	938.5	2848.6	2729.6	1183.7	252.2	319.7	64.6	54.9	4.6	24.42	7.7	8.78
Tek Trol	2	1	2763	4594.7	2.2	7360	9531.2	3769.4	851.3	2504.3	2518.1	1030.7	224.1	301.5	56.5	47.5	3.3	26.61	7.8	7.87
Tek Trol	2	2	2624.2	4700.2	2.4	7326.9	9129.3	3728.3	801	2397	2228.1	997.2	214.1	268.9	55.3	46.9	4.2	26.06	7.7	7.85
Tek Trol	2	3	2953.9	4366.7	1.6	7322.2	9491.7	3827.1	841	2492.6	2474.9	1034.8	221.4	289.2	56.8	48	3.6	26.27	7.8	7.93
Tek Trol	2	10	3739.6	3591.5	2.5	7333.6	9417.6	3818	841.3	2483.9	2393.2	1033.6	220.4	277.3	57.1	47.7	4.1	25.8	7.6	7.95
Tek Trol	2	14	3146.7	3893	2	7041.7	9552.1	3948.8	820.2	2526.7	2392.9	1063.9	224	279.6	58.8	50.1	4.2	25.62	7.8	8.05
Tek Trol	2	21	3498.2	3527	2.3	7027.5	9787.9	3970.5	854.3	2570.4	2420.3	1071.8	228.1	287.9	59.3	49.8	4.3	25.19	7.6	8.19
Tek Trol	2	32	3009.6	4012.8	2.5	7024.8	10136.9	4108.3	888.3	2680.4	2612.2	1113.1	238.9	316.1	61.1	51.5	4	24.42	7.7	8.56
Tek Trol	2	40	3777.7	3074.4	1.8	6854	10971.1	4370.3	957.8	2974.3	2921.9	1209.1	256.4	331.1	65.1	54.6	3.1	24.4	7.8	8.86
Virkon	1	1	2235.8	4751.4	0.8	6988	9579.5	3694.7	815.8	2639.7	2653.9	988.9	225.6	283.5	58.1	49.7	5.7	25.33	7.5	7.58
Virkon	1	2	3010.8	4282.6	0.6	7294	9091.2	3640.2	744.3	2339.5	2211.3	938.2	210.3	262.7	55.4	46.8	4	26.29	7.5	7.49
Virkon	1	3	2770	4545	1	7316	9098	3601.8	777.1	2333.6	2278.4	939.3	212.9	251.9	55.5	47.1	3.9	27.64	7.7	7.65
Virkon	1	10	4363.6	2788.4	1	7153	9101.5	3719.4	763.2	2319.1	2206.9	956.4	211.3	255	56.3	47.3	4.2	27.02	7.7	7.62
Virkon	1	14	3581.6	3320.6	0.8	6903	9384.2	3654.5	805.3	2456.8	2496	965.3	217.3	267	57.4	47.6	3.1	26.54	7.5	7.68
Virkon	1	21	4301	2833.3	0.7	7135	9482.7	3836.7	809.6	2536.5	2335.3	1005.1	225.2	260.8	59.2	50.8	4.2	26.39	7.5	7.71
Virkon	1	32	3642.4	3710.6	1	7354	10127.1	4064.1	845.7	2642.2	2378.6	1058.7	229.3	283.6	62.1	51.8	4.6	26.47	7.6	7.82
Virkon	1	40	5005.4	2422.7	0.9	7429	10972.5	4327	993.6	2943.8	2696.4	1132.6	262.8	316.5	67.3	58.1	4.7	26.86	7.6	8.3

Table A5: Nutrient content data processed post disinfectant experiment.

Disinfectant	Replication	Days Post Dosing	Org. N	NH3-N	Nit. N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
Virkon	2	1	6002.4	1119.6	1.1	7123	9471.5	3629.1	791.1	2467	2448	957.2	218	267.5	57.5	47.5	3.9	27.17	7.6	7.67
Virkon	2	2	4685.3	2725.1	0.6	7411	9540.1	3652.3	794.2	2524.8	2566	969.5	224	270.6	57.6	48.9	3	26.13	7.5	7.62
Virkon	2	3	5068.5	2238.5	1	7308	9631.4	3726.1	808.3	2494.7	2453.3	983.2	227.1	279.8	58.8	49.8	4	25.36	7.6	7.69
Virkon	2	10	4750.4	2506.1	1.5	7258	9728.9	3752.7	795.5	2490.4	2437.3	984	225	270.8	58.7	49.4	4.3	26.85	7.7	7.68
Virkon	2	14	3979	3251.2	0.7	7231	9744.6	3769.7	815.5	2592.1	2474.6	989.2	227.2	274.1	59	49.8	4.3	25.7	7.5	7.7
Virkon	2	21	4369.4	3113.6	1.1	7484	10520.7	3913.7	914.4	2918.4	2726.1	1049.4	251.7	296.5	63.7	54.5	3.6	26.82	7.5	8.08
Virkon	2	32	5326.2	2240.8	2	7569	10516.8	4154	864.3	2798.1	2450.4	1092.8	237.4	285.7	65	55.1	4.7	27.26	7.6	7.99
Virkon	2	40	5167	2716.1	2.8	7886	11652.3	4399.2	1057.8	3105.3	2927.8	1165.6	278.9	341.9	70.1	60	4.3	26.77	7.6	8.53

Table A6: Antibiotic data for the disinfectant experiment

Disinfectant	Reactor (1or2)	Days Post Dosing	Chlortetracycline	Lincomycin	Tiamulin	% Oleandomycin
			ng/g	ng/g	ng/g	%
none	Composite	0	12349.3	133.4	61.4	141.7
Chlorine Bleach	1	1	13622.6	154.2	97.5	138.4
Chlorine Bleach	1	5	7812.2	320.8	56.5	129.9
Chlorine Bleach	1	14	13248.2	147.6	41.0	79.3
Chlorine Bleach	1	21	14773.8	287.7	170.9	202.4
Chlorine Bleach	1	40	16785.9	646.3	177.0	216.7
Chlorine Bleach	2	1	18823.2	591.0	82.2	136.0
Chlorine Bleach	2	5	6710.0	293.3	47.8	156.7
Chlorine Bleach	2	14	12129.5	276.9	59.7	94.9
Chlorine Bleach	2	21	12506.4	1053.5	167.5	189.1
Chlorine Bleach	2	40	14787.5	721.0	217.7	286.2
Virkon	1	1	12660.3	154.1	273.6	104.1
Virkon	1	5	1824.4	723.3	60.6	83.2
Virkon	1	14	13719.3	257.1	115.8	61.9
Virkon	1	21	11419.7	1164.2	159.6	234.4
Virkon	1	40	16805.5	1120.0	263.6	156.1
Virkon	2	1	10866.8	103.7	59.8	125.0
Virkon	2	5	8538.3	373.0	68.1	136.5
Virkon	2	14	11245.6	1013.6	61.8	90.8
Virkon	2	21	13900.5	521.6	248.8	202.1
Virkon	2	40	15881.7	610.1	170.2	141.1
Pi-Quat	1	1	8152.2	77.0	196.4	182.1
Pi-Quat	1	5	14369.9	577.8	236.1	170.2
Pi-Quat	1	14	10946.9	1950.3	251.7	115.7
Pi-Quat	1	21	13800.6	2127.0	371.4	277.4
Pi-Quat	1	40	12541.7	412.6	438.7	190.7
Pi-Quat	2	1	11151.3	826.4	269.3	177.9
Pi-Quat	2	5	4905.0	1109.5	160.2	43.1
Pi-Quat	2	14	11573.3	1010.0	251.7	102.5
Pi-Quat	2	21	11855.9	659.6	376.8	209.4
Pi-Quat	2	40	17137.8	1014.6	275.3	161.2
Tek Trol	1	1	12502.6	929.2	17.8	18.8
Tek Trol	1	5	3281.3	788.1	24.5	17.9
Tek Trol	1	14	9586.5	1910.8	30.0	139.4
Tek Trol	1	21	11463.7	566.5	89.9	192.4
Tek Trol	1	40	7858.8	1152.6	23.9	16.3
Tek Trol	2	1	7869.5	402.6	13.0	15.2
Tek Trol	2	5	188392.1	851.2	9.0	14.6
Tek Trol	2	14	8327.8	1172.4	23.6	12.9
Tek Trol	2	21	9122.2	209.3	55.0	24.5
Tek Trol	2	40	7838.6	438.8	23.0	10.2
Control	1	1	16264.7	178.8	80.2	132.3
Control	1	5	8348.6	159.6	86.8	93.7

Control	1	14	11293.8	892.6	133.2	155.6
Control	1	21	14824.2	1077.2	389.9	203.4
Control	1	40	13874.3	1818.8	346.6	185.2
Control	2	1	11209.7	160.3	49.0	134.2
Control	2	5	12064.0	1075.2	93.7	88.4
Control	2	14	6650.8	51.4	88.6	87.9
Control	2	21	12255.1	79.9	171.0	206.8
Control	2	40	12920.8	917.0	213.8	142.3

Appendix B: Normalized Data

Table B1: Physical properties of the manure slurry recorded during the additives experiment

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
			°C	°C	°C		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Coban 90	1	1	1.013	0.881	1.122	0.939	1.800	1.294	0.535	0.496	1.337	0.543	0.974
Coban 90	1	2	0.993	0.892	1.081	0.940	1.000	1.090	0.609	0.604	1.035	0.781	
Coban 90	1	5	0.961	0.892	0.959	0.945	1.000	0.780	0.946	0.943	0.932	1.090	1.010
Coban 90	1	10	0.876	0.886	0.976	0.951	1.200	0.788	0.965	0.968	1.059	1.042	
Coban 90	1	14	0.889	0.784	0.902	0.940	1.000	0.963	1.559	1.636	1.057		
Coban 90	1	21	1.059	0.920	0.911	0.968	0.800	0.861	0.982	0.978	0.994	1.003	0.975
Coban 90	1	32	0.987	0.858	0.943	0.971	1.000	1.159	0.976	0.966	1.079	1.135	1.000
Coban 90	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Coban 90	2	1	1.013	0.800	1.242	0.996	1.200	0.987	0.806	0.805	0.712	0.776	1.013
Coban 90	2	2	0.987	0.889	1.094	0.959	1.200	1.145	0.901	0.954	0.725	0.691	
Coban 90	2	5	0.934	0.889	0.953	0.975	1.200	0.888	0.916	0.920	0.801	0.777	0.992
Coban 90	2	10	0.881	0.844	0.969	0.977	1.200	0.637	0.924	0.932	0.946	0.972	
Coban 90	2	14	0.874	0.783	0.875	0.986	1.000	1.026	0.551	0.548	0.973		
Coban 90	2	21	1.073	0.900	0.898	0.997	1.000	0.818	0.970	0.980	2.517	1.168	1.024
Coban 90	2	32	1.007	0.844	0.883	0.991	1.000	0.894	0.985	0.983	1.016	1.113	1.001
Coban 90	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Control	1	1	1.013	0.863	1.087	0.946	1.250	1.062	0.896	0.938	1.008	1.079	0.995
Control	1	2	0.987	0.869	1.048	0.971	1.750	1.267	0.883	0.987	0.796	0.776	
Control	1	5	0.916	0.869	0.897	0.964	1.250	0.704	0.978	1.114	0.906	0.957	0.996
Control	1	10	0.858	0.885	0.944	0.968	1.250	0.778	0.856	0.877	0.941	1.059	
Control	1	14	0.884	0.765	0.865	0.967	1.250	0.823	0.907	0.706	0.864		
Control	1	21	1.097	0.929	0.698	0.975	1.000	1.021	0.944	0.966	0.897	1.040	1.003
Control	1	32	0.974	0.836	0.698	0.979	1.000	1.066	1.000	1.009	0.944	1.130	1.002
Control	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Control	2	1	1.000	1.097	1.118	0.958	1.800	1.103	0.814	0.836	0.869	1.024	0.999
Control	2	2	0.973	0.880	1.084	0.958	1.200	1.186	0.659	0.661	0.834	0.822	
Control	2	5	1.000	0.880	0.941	0.985	1.200	0.833	0.797	0.759	0.808	0.958	1.003
Control	2	10	0.833	0.869	0.950	0.986	1.200	0.867	0.852	0.860	0.856	0.887	
Control	2	14	0.873	0.760	0.866	0.976	1.000	0.882	0.865	0.881	0.901		
Control	2	21	1.080	0.926	0.891	0.983	1.200	0.871	0.871	0.866	0.744	1.034	0.999
Control	2	32	0.953	0.840	0.899	0.995	1.000	0.821	0.808	0.792	0.905	1.060	1.000
Control	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Manure Magic	1	1	1.000	0.883	1.117	0.961	1.200	1.052	0.853	0.870	0.703	0.795	0.995

Table B1: Physical properties of the manure slurry recorded during the additives experiment

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Manure Magic	1	2	0.981	0.900	1.102	0.962	1.000	1.080	0.630	0.601	0.842	0.769	
Manure Magic	1	5	0.955	0.900	0.969	0.986	1.200	0.810	0.866	0.893	0.773	0.911	1.009
Manure Magic	1	10	0.873	0.894	0.969	0.985	1.000	1.021	0.829	0.843	0.767	0.908	
Manure Magic	1	14	0.879	0.794	0.688	0.977	1.000	0.886	0.442	0.439	0.890		
Manure Magic	1	21	1.083	0.950	0.688	0.986	1.000	0.969	0.878	0.889	0.943	1.080	1.027
Manure Magic	1	32	0.936	0.828	0.898	0.989	0.800	0.810	0.917	0.924	1.035	1.053	1.003
Manure Magic	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Manure Magic	2	1	1.020	0.857	1.120	0.964	1.750	1.068	0.893	0.935	0.567	1.095	0.992
Manure Magic	2	2	1.000	0.868	1.088	0.970	1.750	1.382	0.767	0.794	0.853	0.838	
Manure Magic	2	5	0.980	0.000	0.952	0.987	1.250	0.984	0.870	0.890	0.848	1.085	1.000
Manure Magic	2	10	0.895	0.874	0.944	0.987	1.500	1.028	0.888	0.908	0.808	1.010	
Manure Magic	2	14	0.876	0.769	0.880	0.986	1.250	0.992	0.889	0.912	0.917		
Manure Magic	2	21	1.052	0.890	0.912	0.984	1.250	0.980	0.938	0.972	0.925	1.025	1.002
Manure Magic	2	32	0.993	0.835	0.920	0.991	2.750	0.829	0.952	0.952	0.895	1.248	1.000
Manure Magic	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MOC-7	1	1	1.031	0.930	1.211	0.999	2.000	1.225	0.734	0.766	0.880	0.514	0.993
MOC-7	1	2	1.019	0.951	1.188	1.009	1.000	1.164	0.943	1.005	0.732	0.782	
MOC-7	1	5	0.950	0.951	1.023	0.952	1.000	1.037	0.929	0.965	0.996	0.900	0.989
MOC-7	1	10	0.894	0.881	1.063	0.988	1.000	0.957	0.946	0.991	0.668	1.118	
MOC-7	1	14	0.881	0.881	0.930	0.958	1.500	0.870	0.914	0.963	0.741		
MOC-7	1	21	1.069	0.941	1.000	0.983	1.000	1.108	0.916	0.944	0.978	1.124	1.002
MOC-7	1	32	1.000	0.838	0.969	0.994	1.000	1.096	0.955	0.973	0.894	1.266	1.000
MOC-7	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MOC-7	2	1	1.073	0.930	1.134	0.972	3.250	1.186	0.839	0.900	0.820	1.090	1.003
MOC-7	2	2	1.046	0.951	1.119	1.033	1.250	0.865	0.796	0.822	0.754	0.780	
MOC-7	2	5	0.974	0.951	0.955	0.959	1.250	1.068	0.988	1.031	0.756	0.391	1.004
MOC-7	2	10	0.907	0.000	1.000	0.969	1.500	1.176	0.967	0.998	0.791	0.873	
MOC-7	2	14	0.901	0.778	0.828	0.969	1.500	1.166	0.831	0.851	0.878		
MOC-7	2	21	1.066	0.924	0.933	0.980	0.750	0.895	1.014	1.035	0.731	1.179	1.011
MOC-7	2	32	1.040	0.870	0.873	1.001	1.250	1.196	1.026	1.032	0.948	1.003	1.002
MOC-7	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
More Than Manure	1	1	1.026	0.905	1.108	0.994	1.000	0.902	0.718	0.730	0.891	0.386	
More Than Manure	1	2	0.994	0.927	1.108	1.011	1.000	0.916	0.339	0.323	0.896	0.750	
More Than Manure	1	5	0.942	0.927	0.954	0.963	0.778	0.929	0.952	0.983	1.055	1.032	1.039
More Than Manure	1	10	0.885	0.916	1.000	0.984	1.444	0.967	0.929	0.947	0.984	1.071	
More Than Manure	1	14	0.878	0.810	0.677	0.952	2.667	1.071	0.965	0.969	0.902		
More Than Manure	1	21	1.077	0.939	0.908	0.980	0.667	0.978	0.955	0.962	0.911	1.109	1.000
More Than Manure	1	32	0.929	0.844	0.892	0.986	0.667	0.859	0.976	0.974	1.080	1.200	1.003

Table B1: Physical properties of the manure slurry recorded during the additives experiment

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
More Than Manure	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
More Than Manure	2	1	1.048	0.957	0.941	0.961	1.000	0.992	0.694	0.706	0.840	0.713	1.000
More Than Manure	2	2	1.060	0.978	1.132	0.943	1.500	1.022	0.000	0.000	0.325	0.421	
More Than Manure	2	5	0.988	0.978	0.963	0.950	1.500	0.920	0.928	0.965	0.952	0.682	
More Than Manure	2	10	0.874	0.984	1.029	0.979	4.250	0.989	0.935	0.964	0.929	0.734	
More Than Manure	2	14	0.916	0.860	0.897	0.973	1.250	1.030	0.806	0.810	0.797		
More Than Manure	2	21	1.072	0.968	0.971	0.983	1.500	0.956	0.987	1.004	0.938	0.883	1.012
More Than Manure	2	32	0.970	0.914	0.934	0.991	1.250	1.066	0.979	0.986	0.927	0.931	1.002
More Than Manure	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sludge Away	1	1	1.000	0.935	1.111	0.925	6.250	1.101	0.499	0.522	0.912	0.572	0.998
Sludge Away	1	2	0.980	0.935	1.095	0.985	4.250	1.077	0.831	0.865	0.370	0.378	
Sludge Away	1	5	0.934	0.000	1.095	0.977	1.250	0.920	0.935	0.980	0.856	0.829	1.001
Sludge Away	1	10	0.888	0.912	1.008	0.956	1.500	0.817	0.948	0.976	0.961	0.933	
Sludge Away	1	14	0.882	0.824	0.921	0.966	1.250	0.859	0.862	0.862	0.800		
Sludge Away	1	21	1.059	0.947	0.952	0.972	1.000	0.928	0.966	0.981	0.965	1.110	1.009
Sludge Away	1	32	0.914	0.853	0.944	0.973	1.250	0.862	1.014	1.034	0.918	1.095	1.003
Sludge Away	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.001
Sludge Away	2	1	0.974	0.931	1.110	0.940	1.333	1.185	0.691	0.725	0.897	1.777	1.000
Sludge Away	2	2	0.955	0.926	1.102	1.005	2.000	1.372	0.808	0.821	0.684	0.690	
Sludge Away	2	5	0.917	0.971	0.953	0.935	2.333	1.124	0.919	0.962	0.860	0.860	0.997
Sludge Away	2	10	0.865	0.920	1.000	0.942	1.667	1.050	0.886	0.911	0.856	0.944	
Sludge Away	2	14	0.904	0.840	0.953	0.978	6.000	1.097	0.788	0.787	0.810		
Sludge Away	2	21	1.051	0.937	0.969	0.967	1.333	1.077	0.899	0.921	0.925	1.137	1.011
Sludge Away	2	32	0.917	0.874	0.929	0.979	1.333	1.161	0.928	0.937	0.843	1.330	1.001
Sludge Away	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sulfi-Doxx	1	1	1.013	0.920	1.124	0.994	1.500	1.102	0.651	0.667	0.723	0.983	0.996
Sulfi-Doxx	1	2	0.994	0.932	1.132	0.988	1.000	1.242	0.675	0.684	0.791	0.608	
Sulfi-Doxx	1	5	0.935	0.932	1.000	0.965	1.750	0.801	0.644	0.667	0.704	0.683	1.006
Sulfi-Doxx	1	10	0.897	0.932	1.031	0.957	1.250	0.901	0.889	0.918	0.794	0.876	
Sulfi-Doxx	1	14	0.890	0.835	0.938	0.985	1.250	0.930	0.917	0.932	0.910		
Sulfi-Doxx	1	21	1.052	0.932	0.984	0.978	1.000	0.901	0.926	0.950	0.869	0.961	1.000
Sulfi-Doxx	1	32	0.929	0.858	0.930	0.985	1.000	0.726	0.956	0.955	0.705	1.093	0.999
Sulfi-Doxx	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sulfi-Doxx	2	1	1.013	0.914	1.141	0.965	1.500	1.110	0.785	0.815	0.792	0.686	0.998
Sulfi-Doxx	2	2	0.994	0.943	1.125	0.985	2.500	1.209	0.505	0.504	0.731	0.707	
Sulfi-Doxx	2	5	0.942	0.937	1.000	0.962	1.250	1.045	0.988	1.155	0.778	0.789	1.028
Sulfi-Doxx	2	10	0.000	0.000	0.000	0.968	1.000	0.901	0.973	1.001	0.804	0.921	
Sulfi-Doxx	2	14	0.897	0.983	0.688	0.973	1.000	0.884	0.927	0.938	0.818		

Table B1: Physical properties of the manure slurry recorded during the additives experiment

Additive	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Sulfi-Doxx	2	21	1.052	0.937	0.969	0.979	1.000	0.836	0.965	0.980	0.877	1.059	1.003
Sulfi-Doxx	2	32	0.916	0.857	0.953	0.983	1.000	1.020	0.993	0.992	1.001	1.246	1.002
Sulfi-Doxx	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B2: Nutrient content of the slurry recorded from the additives experiment normalized by the day 40 value.

Additive	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
			ppm N	ppm N	ppm N	ppm N	ppm P2O5	ppm K2O	ppm S	ppm Ca	ppm Mg	ppm Na	ppm Zn	ppm Fe	ppm Mn	ppm Cu	ppm B	mmho/cm		%
Coban 90	1	1	0.597	1.496	1.583	1.023	0.908	0.853	0.898	0.863	0.869	0.912	0.921	0.883	0.909	0.907	0.920	1.089	0.975	0.919
Coban 90	1	2	0.727	1.359	0.917	1.026	0.931	0.823	0.909	0.858	0.847	0.915	0.938	0.899	0.923	0.907	0.900	1.098	0.975	0.927
Coban 90	1	5	0.741	1.321	0.917	1.016	0.934	0.827	0.946	0.868	0.834	0.943	0.969	0.953	0.936	0.950	0.920	1.087	0.975	0.934
Coban 90	1	10	1.003	1.061	1.917	1.031	0.961	0.919	1.018	0.988	0.922	0.952	0.988	0.952	0.973	0.950	0.940	1.061	0.988	0.949
Coban 90	1	14	0.768	1.295	2.500	1.020	0.956	0.952	0.944	0.967	0.954	0.957	0.973	0.927	0.960	0.938	0.940	1.074	0.975	0.934
Coban 90	1	21	1.178	0.867	3.083	1.031	0.966	0.941	0.986	0.958	0.902	1.013	1.026	0.997	0.980	0.978	1.000	1.078	0.988	0.954
Coban 90	1	32	0.859	1.169	0.917	1.006	0.982	0.983	0.998	0.972	0.966	1.004	0.993	0.988	0.990	1.003	0.980	1.030	0.988	0.988
Coban 90	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Coban 90	2	1	0.865	1.318	1.286	0.999	0.909	0.915	0.893	0.925	0.900	0.911	0.924	0.907	0.907	0.908	0.927	0.972	0.975	0.920
Coban 90	2	2	0.930	1.238	0.786	1.021	0.913	0.911	0.909	0.888	0.907	0.889	0.937	0.970	0.893	0.886	0.891	0.975	0.975	0.933
Coban 90	2	5	0.909	1.304	3.000	1.026	0.910	0.881	0.890	0.871	0.892	0.888	0.899	0.957	0.895	0.899	0.855	0.968	0.975	0.937
Coban 90	2	10	0.833	1.412	1.429	1.004	0.928	0.883	0.958	0.905	0.883	0.901	0.944	0.939	0.898	0.924	0.909	0.959	0.987	0.949
Coban 90	2	14	0.773	1.370	1.286	0.949	0.933	0.909	0.944	0.901	0.918	0.913	0.925	0.939	0.916	0.919	0.909	0.938	0.975	0.951
Coban 90	2	21	0.731	1.614	1.571	0.992	0.932	0.937	0.947	0.935	0.956	0.909	0.925	0.924	0.927	0.935	0.909	0.937	0.987	0.945
Coban 90	2	32	1.095	0.899	1.857	1.037	0.947	0.974	0.948	0.964	0.959	0.953	0.955	0.951	0.932	0.933	1.000	0.928	0.987	0.977
Coban 90	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Control	1	1	0.888	1.067	1.833	0.982	0.876	0.891	0.829	0.828	0.860	0.905	0.853	0.776	0.867	0.863	0.900	0.946	0.975	0.897
Control	1	2	0.894	1.138	1.417	1.022	0.896	0.904	0.843	0.846	0.867	0.936	0.874	0.811	0.896	0.879	0.920	1.069	0.975	0.901
Control	1	5	0.916	1.095	2.083	1.010	0.920	0.893	0.914	0.864	0.861	0.945	0.919	0.887	0.910	0.901	0.940	1.051	0.963	0.913
Control	1	10	0.996	1.029	2.500	1.014	0.915	0.903	0.899	0.850	0.870	0.931	0.907	0.836	0.901	0.896	0.920	1.024	0.975	0.913
Control	1	14	1.012	1.032	0.917	1.022	0.929	0.907	0.901	0.856	0.876	0.954	0.913	0.897	0.928	0.910	0.900	1.036	0.975	0.928
Control	1	21	0.976	1.011	0.917	0.994	0.946	0.926	0.933	0.856	0.896	0.982	0.933	0.988	0.936	0.932	0.960	0.951	0.975	0.930
Control	1	32	0.987	1.020	0.917	1.005	1.014	0.970	0.993	0.957	0.961	1.019	1.013	1.017	1.029	1.005	1.020	0.959	0.988	0.989
Control	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Control	2	1	0.893	1.106	0.923	1.004	0.779	0.860	0.725	0.764	0.798	0.839	0.772	0.764	0.778	0.762	0.807	1.143	0.987	0.803
Control	2	2	0.860	1.068	0.923	0.968	0.807	0.877	0.739	0.800	0.814	0.877	0.797	0.801	0.805	0.774	0.825	1.134	0.975	0.846
Control	2	5	0.917	1.026	0.923	0.974	0.813	0.872	0.744	0.802	0.812	0.870	0.792	0.800	0.810	0.788	0.825	1.137	0.975	0.874
Control	2	10	1.040	0.982	0.923	1.010	0.851	0.881	0.820	0.818	0.837	0.905	0.831	0.864	0.850	0.828	0.807	1.073	0.975	0.876
Control	2	14	0.846	1.070	0.923	0.963	0.858	0.900	0.775	0.860	0.862	0.894	0.835	0.841	0.853	0.826	0.842	1.129	0.987	0.882
Control	2	21	0.885	0.978	1.000	0.934	0.835	0.906	0.791	0.785	0.832	0.906	0.813	0.793	0.825	0.802	0.860	1.110	0.987	0.866
Control	2	32	0.913	0.966	1.000	0.941	0.868	0.945	0.818	0.822	0.851	0.959	0.859	0.917	0.853	0.847	0.895	1.081	0.987	0.882
Control	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Manure Magic	1	1	0.998	1.002	1.182	1.000	0.586	0.626	0.583	0.531	0.576	0.624	0.621	0.614	0.576	0.560	0.630	1.082	0.975	0.846
Manure Magic	1	2	1.231	0.687	1.091	0.990	0.758	0.800	0.775	0.695	0.740	0.801	0.785	0.771	0.739	0.723	0.796	1.075	0.987	0.863
Manure Magic	1	5	1.038	0.910	1.091	0.981	0.859	0.903	0.837	0.789	0.850	0.916	0.872	0.862	0.856	0.820	0.889	1.075	0.975	0.867
Manure Magic	1	10	0.683	1.354	1.000	0.981	0.838	0.920	0.868	0.796	0.849	0.909	0.870	0.847	0.835	0.818	0.889	1.057	0.975	0.863
Manure Magic	1	14	0.781	1.262	1.091	0.994	0.847	0.893	0.856	0.798	0.830	0.900	0.881	0.872	0.842	0.820	0.889	1.057	0.987	0.844
Manure Magic	1	21	0.799	1.199	1.000	0.977	0.879	0.957	0.865	0.842	0.883	0.935	0.907	0.873	0.864	0.831	0.907	1.063	0.987	0.875

Table B2: Nutrient content of the slurry recorded from the additives experiment normalized by the day 40 value.

Additive	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
Manure Magic	1	32	0.803	1.199	1.000	0.979	0.920	0.966	0.921	0.895	0.923	0.960	0.962	0.918	0.918	0.895	0.981	1.037	1.000	0.928
Manure Magic	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Manure Magic	2	1	1.419	0.659	0.529	0.986	0.845	0.906	0.891	0.872	0.867	0.892	0.855	0.846	0.863	0.866	0.868	1.034	0.975	0.885
Manure Magic	2	2	1.109	0.929	0.588	1.006	0.888	0.911	0.879	0.892	0.885	0.902	0.893	0.871	0.889	0.872	0.925	1.027	0.975	0.889
Manure Magic	2	5	1.183	0.824	0.588	0.978	0.899	0.940	0.861	0.872	0.896	0.931	0.908	0.887	0.881	0.877	0.943	1.038	0.975	0.864
Manure Magic	2	10	1.149	0.852	0.706	0.980	0.879	0.928	0.883	0.857	0.869	0.936	0.890	0.865	0.881	0.874	0.925	1.032	0.975	0.872
Manure Magic	2	14	1.330	0.719	0.765	0.981	0.886	0.925	0.881	0.866	0.890	0.921	0.885	0.864	0.868	0.879	0.906	1.032	0.975	0.885
Manure Magic	2	21	1.092	0.886	0.647	0.975	0.889	0.964	0.898	0.884	0.907	0.940	0.898	0.935	0.887	0.884	0.925	1.030	1.000	0.870
Manure Magic	2	32	0.969	0.951	0.588	0.959	0.920	0.981	0.904	0.957	0.937	0.961	0.931	0.916	0.923	0.917	0.962	1.016	0.987	0.924
Manure Magic	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MOC-7	1	1	0.907	1.096	1.000	0.979	0.913	0.945	0.898	0.936	0.948	0.915	0.933	0.905	0.946	0.935	0.926	1.054	0.975	0.924
MOC-7	1	2	1.020	0.894	1.100	0.972	0.875	0.897	0.861	0.861	0.890	0.891	0.877	0.845	0.898	0.880	0.889	1.063	0.975	0.903
MOC-7	1	5	0.983	0.888	1.000	0.947	0.887	0.916	0.842	0.874	0.903	0.909	0.874	0.867	0.917	0.885	0.889	1.030	0.975	0.916
MOC-7	1	10	0.994	0.977	1.100	0.988	0.931	0.919	0.911	0.933	0.912	0.930	0.954	0.916	0.952	0.918	0.944	1.011	0.975	0.950
MOC-7	1	14	0.931	0.972	1.000	0.947	0.902	0.925	0.885	0.896	0.908	0.916	0.892	0.886	0.916	0.898	0.907	1.017	0.975	0.926
MOC-7	1	21	1.026	0.937	1.000	0.992	0.950	0.968	0.955	0.985	0.984	0.939	0.954	0.919	0.964	0.942	0.963	1.056	0.987	0.973
MOC-7	1	32	0.941	0.988	1.000	0.959	0.740	0.753	0.720	0.752	0.751	0.739	0.737	0.731	0.736	0.735	0.759	1.015	1.000	0.974
MOC-7	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MOC-7	2	1	1.216	0.820	0.714	1.015	0.843	0.849	0.847	0.840	0.850	0.822	0.848	0.839	0.842	0.847	0.828	1.060	0.975	0.923
MOC-7	2	2	1.294	0.667	0.929	0.976	0.864	0.855	0.893	0.811	0.849	0.847	0.870	0.827	0.857	0.864	0.879	1.022	0.987	0.923
MOC-7	2	5	1.423	0.608	0.786	1.010	0.882	0.836	0.912	0.842	0.845	0.858	0.883	0.856	0.885	0.883	0.862	1.010	0.975	0.941
MOC-7	2	10	0.698	1.282	0.786	0.994	0.909	0.885	0.914	0.917	0.890	0.882	0.909	0.872	0.915	0.914	0.879	1.066	0.975	0.960
MOC-7	2	14	0.917	1.078	0.929	0.999	0.899	0.891	0.910	0.872	0.896	0.876	0.885	0.872	0.879	0.876	0.897	1.040	0.987	0.944
MOC-7	2	21	0.924	1.089	0.714	1.007	0.905	0.876	0.912	0.852	0.869	0.886	0.897	0.868	0.895	0.902	0.897	1.020	0.975	0.967
MOC-7	2	32	0.978	1.068	1.143	1.023	0.938	0.919	0.927	0.955	0.942	0.912	0.927	0.929	0.945	0.943	0.914	1.026	0.987	1.009
MOC-7	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
More Than Manure	1	1	0.722	1.385	1.500	1.012	0.885	0.866	0.911	0.870	0.852	0.887	0.919	0.871	0.890	0.878	0.909	1.014	0.987	0.914
More Than Manure	1	2	0.696	1.400	1.857	1.004	0.908	0.884	0.922	0.911	0.882	0.888	0.928	0.882	0.904	0.889	0.927	1.027	0.975	0.926
More Than Manure	1	5	0.797	1.264	1.429	1.001	0.875	0.874	0.882	0.884	0.866	0.869	0.873	0.863	0.872	0.883	0.873	1.021	0.975	0.926
More Than Manure	1	10	0.824	1.201	0.929	0.989	0.905	0.888	0.925	0.918	0.883	0.911	0.942	0.889	0.916	0.917	0.927	1.037	0.975	0.945
More Than Manure	1	14	1.065	0.965	2.786	1.022	0.930	0.916	0.972	0.949	0.914	0.934	0.968	0.973	0.940	0.941	0.945	1.010	0.987	0.957
More Than Manure	1	21	0.771	1.246	2.429	0.979	0.947	0.938	0.942	0.950	0.940	0.940	0.975	0.917	0.939	0.937	0.982	1.024	0.975	0.948
More Than Manure	1	32	0.942	1.109	0.929	1.015	0.984	0.967	0.988	0.986	0.978	0.979	1.017	0.992	0.989	0.986	1.018	1.017	0.987	0.983
More Than Manure	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
More Than Manure	2	1	0.983	0.991	1.077	0.987	0.789	0.812	0.752	0.792	0.792	0.792	0.744	0.764	0.786	0.782	0.770	1.020	0.975	0.874
More Than Manure	2	2	1.111	0.903	1.000	1.007	0.830	0.844	0.813	0.805	0.839	0.822	0.797	0.831	0.825	0.809	0.803	1.028	0.987	0.892
More Than Manure	2	5	0.966	1.021	1.000	0.994	0.840	0.853	0.800	0.827	0.837	0.841	0.820	0.826	0.836	0.822	0.820	1.032	0.962	0.888
More Than Manure	2	10	1.021	0.960	1.000	0.990	0.868	0.869	0.845	0.890	0.876	0.851	0.856	0.874	0.864	0.851	0.836	1.027	0.962	0.908
More Than Manure	2	14	0.982	1.017	1.000	0.999	0.856	0.891	0.841	0.853	0.866	0.871	0.843	0.884	0.848	0.835	0.852	1.031	0.987	0.901

Table B2: Nutrient content of the slurry recorded from the additives experiment normalized by the day 40 value.

Additive	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	Na	Zn	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
More Than Manure	2	21	0.999	0.977	1.077	0.988	0.910	0.912	0.919	0.916	0.915	0.913	0.906	0.933	0.925	0.906	0.902	1.016	0.987	0.956
More Than Manure	2	32	0.995	0.997	1.000	0.996	0.931	0.930	0.898	0.935	0.934	0.932	0.917	0.976	0.937	0.927	0.934	1.010	0.987	0.960
More Than Manure	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sludge Away	1	1	0.880	1.120	1.000	0.997	0.925	0.919	0.940	0.862	0.911	0.928	0.967	0.933	0.938	0.917	0.943	1.007	0.987	0.841
Sludge Away	1	2	0.910	1.099	2.000	1.002	0.941	0.905	0.938	0.843	0.894	0.952	0.976	0.945	0.938	0.922	0.981	1.030	0.974	0.649
Sludge Away	1	5	1.146	0.875	1.100	1.013	0.952	0.906	0.990	0.897	0.902	0.973	0.989	0.969	0.970	0.950	1.000	1.006	1.000	0.913
Sludge Away	1	10	0.959	1.026	1.000	0.992	0.977	0.923	0.981	0.903	0.925	0.987	1.011	0.976	0.981	0.967	0.981	1.030	0.987	0.939
Sludge Away	1	14	1.095	0.874	1.000	0.987	0.940	0.899	0.960	0.889	0.892	0.945	0.989	0.945	0.940	0.922	0.981	1.003	0.987	0.913
Sludge Away	1	21	0.944	0.966	1.100	0.955	0.997	0.993	1.009	0.935	0.987	1.015	1.032	1.003	1.009	0.985	1.038	1.015	0.987	0.949
Sludge Away	1	32	0.888	1.110	1.000	0.996	1.000	1.003	1.001	0.920	0.981	1.036	1.045	1.011	1.000	0.987	1.038	1.021	1.000	0.959
Sludge Away	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sludge Away	2	1	0.829	1.146	1.100	0.962	0.879	0.885	0.833	0.850	0.864	0.910	0.842	0.880	0.815	0.813	0.895	1.027	0.975	0.891
Sludge Away	2	2	0.903	1.079	1.300	0.977	0.879	0.863	0.815	0.798	0.848	0.911	0.821	0.865	0.797	0.805	0.895	1.027	0.975	0.879
Sludge Away	2	5	0.780	1.247	1.400	0.976	0.922	0.899	0.898	0.876	0.892	0.935	0.893	0.928	0.833	0.841	0.912	1.019	0.987	0.909
Sludge Away	2	10	0.972	1.058	1.300	1.008	0.864	0.893	0.822	0.842	0.868	0.884	0.847	0.847	0.882	0.844	0.860	1.039	0.975	0.899
Sludge Away	2	14	0.776	1.270	1.400	0.984	0.889	0.905	0.872	0.853	0.892	0.905	0.869	0.855	0.887	0.849	0.895	1.033	0.975	0.908
Sludge Away	2	21	0.885	1.139	1.800	0.992	0.913	0.899	0.901	0.851	0.889	0.920	0.905	0.881	0.900	0.878	0.930	1.013	0.975	0.924
Sludge Away	2	32	0.949	1.059	2.000	0.995	0.937	0.937	0.892	0.906	0.948	0.925	0.914	0.900	0.915	0.897	0.947	1.016	0.987	0.949
Sludge Away	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sulfi-Doxx	1	1	0.829	1.184	1.000	0.988	0.940	0.942	0.898	0.876	0.919	0.965	0.940	0.950	0.935	0.924	0.909	1.028	0.975	0.893
Sulfi-Doxx	1	2	1.063	0.925	1.000	1.001	0.941	0.913	0.888	0.898	0.906	0.928	0.941	0.926	0.935	0.920	0.909	1.027	0.975	0.902
Sulfi-Doxx	1	5	1.191	0.758	1.000	0.997	0.983	0.950	0.930	0.915	0.937	0.973	0.971	0.998	0.980	0.949	0.909	1.032	0.975	0.905
Sulfi-Doxx	1	10	0.899	1.138	1.000	1.006	0.981	0.949	0.939	0.957	0.943	0.957	0.985	0.958	0.984	0.955	0.945	1.034	0.975	0.930
Sulfi-Doxx	1	14	0.764	1.260	1.000	0.986	0.977	0.975	0.931	0.966	0.960	0.962	0.975	0.963	0.978	0.967	0.964	1.031	0.975	0.912
Sulfi-Doxx	1	21	0.963	1.065	1.077	1.009	0.984	0.976	0.933	0.967	0.968	0.977	0.988	0.971	0.986	0.964	1.000	1.024	0.987	0.938
Sulfi-Doxx	1	32	0.926	1.123	1.077	1.015	1.055	1.038	0.987	1.003	1.032	1.043	1.046	1.054	1.043	1.007	1.073	1.006	0.987	0.949
Sulfi-Doxx	1	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sulfi-Doxx	2	1	1.066	1.012	0.933	1.038	0.901	0.869	0.876	0.873	0.886	0.888	0.893	0.872	0.898	0.877	0.879	1.024	0.962	0.944
Sulfi-Doxx	2	2	1.114	0.945	0.867	1.027	0.873	0.860	0.840	0.826	0.867	0.867	0.852	0.826	0.867	0.837	0.845	1.029	0.962	0.934
Sulfi-Doxx	2	5	1.185	0.847	1.000	1.010	0.911	0.888	0.900	0.881	0.892	0.900	0.908	0.886	0.917	0.891	0.862	1.025	0.962	0.946
Sulfi-Doxx	2	10	1.129	0.941	0.867	1.032	0.929	0.895	0.927	0.906	0.905	0.919	0.925	0.925	0.931	0.926	0.897	1.025	0.975	0.953
Sulfi-Doxx	2	14	1.303	0.735	0.867	1.010	0.904	0.897	0.906	0.878	0.899	0.904	0.895	0.897	0.905	0.891	0.897	1.016	0.987	0.943
Sulfi-Doxx	2	21	1.041	0.974	0.933	1.006	0.940	0.905	0.932	0.915	0.915	0.923	0.931	0.942	0.954	0.934	0.931	1.024	0.987	0.961
Sulfi-Doxx	2	32	1.061	0.938	0.933	0.997	0.982	0.951	0.952	0.968	0.967	0.972	0.971	0.977	1.002	0.963	0.966	1.008	0.987	0.994
Sulfi-Doxx	2	40	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table B3: Antibiotics concentrations in the slurry normalized by day 40 for the additives experiment

Additive	Replication	Days Post Dosing	Chlortetracycline	Lincomycin	Tiamulin	Oleandomycin Recovery
			ng/g	ng/g	ng/g	%
Coban 90	1	1	0.583	0.318	0.819	1.810
Coban 90	1	2				
Coban 90	1	5	0.835	2.032	1.283	0.857
Coban 90	1	10				
Coban 90	1	14	0.929	1.989	0.760	1.032
Coban 90	1	21	0.819	2.345	0.444	1.088
Coban 90	1	32				
Coban 90	1	40	1.000	1.000	1.000	1.000
Coban 90	2	1	1.519	0.564	0.864	1.701
Coban 90	2	2				
Coban 90	2	5	2.194	4.742	1.817	0.755
Coban 90	2	10				
Coban 90	2	14	0.753	0.421	0.538	0.965
Coban 90	2	21	1.785	7.978	2.400	1.039
Coban 90	2	32				
Coban 90	2	40	1.000	1.000	1.000	1.000
Control	1	1	0.565	0.379	0.528	1.979
Control	1	2				
Control	1	5	0.765	0.104	1.429	1.072
Control	1	10				
Control	1	14	0.342	0.070	0.495	1.027
Control	1	21	0.161	0.124	0.242	1.132
Control	1	32				
Control	1	40	1.000	1.000	1.000	1.000
Control	2	1	0.315	0.441	0.397	1.721
Control	2	2				
Control	2	5	0.494	1.531	0.491	0.842
Control	2	10				
Control	2	14	0.511	0.892	0.202	0.910
Control	2	21	0.888	0.909	0.145	0.965
Control	2	32				
Control	2	40	1.000	1.000	1.000	1.000
Manure Magic	1	1	0.687	0.638	0.928	1.988
Manure Magic	1	2				
Manure Magic	1	5	0.707	0.427	1.513	0.841
Manure Magic	1	10				

Table B3: Antibiotics concentrations in the slurry normalized by day 40 for the additives experiment

Additive	Replication	Days Post Dosing	Chlortetracycline	Lincomycin	Tiamulin	Oleandomycin Recovery
Manure Magic	1	14	1.301	0.690	0.427	1.048
Manure Magic	1	21	0.572	0.330	0.407	1.168
Manure Magic	1	32				
Manure Magic	1	40	1.000	1.000	1.000	1.000
Manure Magic	2	1	0.864	1.748	0.379	1.895
Manure Magic	2	2				
Manure Magic	2	5	1.783	10.334	1.114	1.092
Manure Magic	2	10				
Manure Magic	2	14	0.896	1.829	0.372	1.046
Manure Magic	2	21	1.771	6.087	0.314	1.143
Manure Magic	2	32				
Manure Magic	2	40	1.000	1.000	1.000	1.000
MOC-7	1	1	0.800	0.185	0.458	1.755
MOC-7	1	2				
MOC-7	1	5	0.576	0.152	0.272	0.831
MOC-7	1	10				
MOC-7	1	14	0.577	0.103	0.272	0.956
MOC-7	1	21	0.575	1.166	0.186	1.001
MOC-7	1	32				
MOC-7	1	40	1.000	1.000	1.000	1.000
MOC-7	2	1	0.843	1.768	0.443	1.719
MOC-7	2	2				
MOC-7	2	5	0.769	0.499	0.235	0.879
MOC-7	2	10				
MOC-7	2	14	0.714	0.728	0.084	1.005
MOC-7	2	21	0.353	0.686	0.074	1.003
MOC-7	2	32				
MOC-7	2	40	1.000	1.000	1.000	1.000
More Than Manure	1	1	0.411	0.350	0.354	1.691
More Than Manure	1	2				
More Than Manure	1	5	0.723	0.112	0.418	0.931
More Than Manure	1	10				
More Than Manure	1	14	0.852	0.813	0.107	0.850
More Than Manure	1	21	0.494	1.335	0.273	0.892
More Than Manure	1	32				
More Than Manure	1	40	1.000	1.000	1.000	1.000
More Than Manure	2	1	1.079	1.522	0.561	1.625
More Than Manure	2	2				
More Than Manure	2	5	0.612	0.409	0.437	0.829

Table B3: Antibiotics concentrations in the slurry normalized by day 40 for the additives experiment

Additive	Replication	Days Post Dosing	Chlortetracycline	Lincomycin	Tiamulin	Oleandomycin Recovery
More Than Manure	2	10				
More Than Manure	2	14	0.651	0.832	0.152	0.919
More Than Manure	2	21	0.609	1.318	0.171	0.958
More Than Manure	2	32				
More Than Manure	2	40	1.000	1.000	1.000	1.000
Sludge Away	1	1	0.391	0.647	0.457	1.591
Sludge Away	1	2				
Sludge Away	1	5	1.004	0.788	0.428	0.697
Sludge Away	1	10				
Sludge Away	1	14	0.473	0.254	0.208	0.920
Sludge Away	1	21	0.739	1.490	0.305	0.969
Sludge Away	1	32				
Sludge Away	1	40	1.000	1.000	1.000	1.000
Sludge Away	2	1	0.821	0.476	0.717	1.754
Sludge Away	2	2				
Sludge Away	2	5	0.783	1.167	0.507	0.943
Sludge Away	2	10				
Sludge Away	2	14	0.772	0.611	0.105	1.008
Sludge Away	2	21	0.246	0.097	0.190	1.073
Sludge Away	2	32				
Sludge Away	2	40	1.000	1.000	1.000	1.000
Sulfi-Doxx	1	1	0.723	1.482	0.675	1.391
Sulfi-Doxx	1	2				
Sulfi-Doxx	1	5	0.846	0.931	0.200	0.742
Sulfi-Doxx	1	10				
Sulfi-Doxx	1	14	0.923	3.205	0.126	1.010
Sulfi-Doxx	1	21	0.599	1.527	0.202	1.092
Sulfi-Doxx	1	32				
Sulfi-Doxx	1	40	1.000	1.000	1.000	1.000
Sulfi-Doxx	2	1	1.224	2.245	0.811	1.715
Sulfi-Doxx	2	2				
Sulfi-Doxx	2	5	0.632	0.181	0.181	0.657
Sulfi-Doxx	2	10				
Sulfi-Doxx	2	14	0.617	0.792	0.093	1.031
Sulfi-Doxx	2	21	0.656	0.752	0.161	1.073
Sulfi-Doxx	2	32				
Sulfi-Doxx	2	40	1.000	1.000	1.000	1.000

Table B4: Physical properties of the slurry recorded during the disinfectants experiment normalized by day 40.

Disinfectant	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
			°C	°C	°C		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Chlorine Bleach	1	1	17.0	17.6	12.8	7.63	0.06	113800	83138	54121	58350	33918	
Chlorine Bleach	1	2	17.3	17.9	16.4	7.80	0.06	79600	79453	51190	60900	26527	92.1%
Chlorine Bleach	1	3	17.7	18.9	15.8	7.57	0.04	96000	82682	53682	52550	28046	91.9%
Chlorine Bleach	1	10	17.4	18.7	12.8	7.89	0.09	85600	83975	53440	50950	24240	92.1%
Chlorine Bleach	1	14	17.2	18.4	12.8	7.89	0.08	86600	80082	51293	69800	28078	91.9%
Chlorine Bleach	1	21	15.5	16.7	13.5	7.74	0.07	77600	80521	51340	58000	21100	91.6%
Chlorine Bleach	1	32	16.7	21.1	14.4	7.53	0.1	82600	80156	49443	53800	18933	91.9%
Chlorine Bleach	1	40	18.3	19.3	15.2	7.97	0.04	79200	81850	50870	70050	26260	91.4%
Chlorine Bleach	2	1	15.9	17.4	15.5	7.60	0.07	94800	80635	51412	59450	38475	
Chlorine Bleach	2	2	17.0	18.0	16.1	9.37	0.03	83800	79697	51658	55600	25413	92.0%
Chlorine Bleach	2	3	18.7	19.3	12.8	7.51	0.06	99000	80842	51966	71750	29058	91.9%
Chlorine Bleach	2	10	17.6	19.1	12.8	7.57	0.11	85600	78925	50375	55800	21210	92.1%
Chlorine Bleach	2	14	17.5	20.3	12.8	7.59	0.05	73400	82611	53051	48850	20402	91.7%
Chlorine Bleach	2	21	16.4	17.9	12.8	7.44	0.07	81800	77873	49208	63300	19000	91.8%
Chlorine Bleach	2	32	16.8	21.4	14.4	7.53	0.04	113800	80705	49711	56850	21262	91.9%
Chlorine Bleach	2	40	18.8	21.4	12.8	7.73	0.02	83400	81340	49746	67100	27068	91.6%
Control	1	1	15.5	16.7	14.2	7.44	0.08	78800	81396	52888	52950	29970	
Control	1	2	18.5	15.9	14.4	7.83	0.07	84600	78263	50775	70950	29565	92.0%
Control	1	3	15.2	16.3	13.7	7.53	0.04	87200	80986	52405	64050	29970	91.8%
Control	1	10	15.7	17.2	15.4	8.10	0.07	83600	80807	52459	56250	24139	91.8%
Control	1	14	15.6	16.0	14.2	7.76	0.06	73200	80353	51752	66650	22725	91.9%
Control	1	21	13.9	15.2	12.9	7.64	0.06	97200	78280	50096	52000	18600	91.9%
Control	1	32	15.3	20.0	13.7	8.66	0.06	83200	81343	50767	58550	25515	91.8%
Control	1	40	16.6	17.7	14.2	7.78	0.04	98800	81270	49791	78350	33431	91.5%
Control	2	1	15.0	15.6	14.6	7.44	0.09	86600	83506	55088	66400	32602	
Control	2	2	15.6	16.4	15.4	7.83	0.11	84400	82641	54402	60850	30931	91.7%
Control	2	3	15.7	16.2	14.8	7.53	0.03	105000	80268	52396	60400	28046	91.5%
Control	2	10	14.8	17.3	14.6	8.10	0.07	90000	83988	54991	67200	22119	91.7%
Control	2	14	15.1	15.5	13.7	7.76	0.07	63200	81638	52870	55300	20200	91.8%
Control	2	21	12.7	15.1	12.0	7.64	0.05	85600	83547	53880	59150	23750	91.4%
Control	2	32	15.2	20.5	13.3	8.66	0.04	78800	84787	52855	57950	24806	91.6%
Control	2	40	16.4	17.8	13.4	7.78	0.04	87200	83970	52032	64650	32421	91.2%
Pi-Quat	1	1	15.3	17.1	15.2	7.46	0.04	83000	83302	54515	61950	29463	
Pi-Quat	1	2	17.1	17.2	15.5	7.38	0.03	55800	80040	52052	80250	31185	91.9%
Pi-Quat	1	3	1.9	17.9	12.8	7.40	0.07	97000	82717	54471	70750	31893	91.7%
Pi-Quat	1	10	16.7	18.4	15.2	7.40	0.08	103200	83725	54991	61750	18483	91.7%
Pi-Quat	1	14	16.6	17.0	14.7	7.55	0.08	94000	83220	54675	58400	16766	91.7%
Pi-Quat	1	21	13.9	16.3	13.4	7.61	0.05	104000	78590	51403	61750	20500	91.6%

Table B4: Physical properties of the slurry recorded during the disinfectants experiment normalized by day 40.

Disinfectant	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Pi-Quat	1	32	16.3	21.7	13.5	7.44	0.06	53600	86442	56102	83950	27540	91.3%
Pi-Quat	1	40	18.3	19.2	14.4	7.47	0.04	105600	88200	57170	71250	26866	90.9%
Pi-Quat	2	1	15.7	16.3	15.2	7.35	0.06	91600	88538	58727	71700	32602	
Pi-Quat	2	2	16.0	16.3	15.0	7.43	0.06	103200	79540	52323	67000	27540	91.9%
Pi-Quat	2	3	17.9	17.9	14.2	7.49	0.06	91600	81092	53381	69050	28957	91.8%
Pi-Quat	2	10	15.5	19.0	14.5	7.36	0.06	94400	83387	54800	52250	22119	91.8%
Pi-Quat	2	14	16.0	16.3	14.1	7.33	0.08	85800	81138	52941	73900	20538	91.8%
Pi-Quat	2	21	13.2	16.6	13.0	7.64	0.07	90600	82762	54368	64100	21300	91.6%
Pi-Quat	2	32	16.1	22.3	13.3	7.70	0.07	83000	86352	56295	80100	23591	91.2%
Pi-Quat	2	40	18.9	20.4	14.0	7.51	0.05	92200	87767	56780	70450	26260	90.9%
Tek Trol	1	1	15.1	16.7	14.7	7.37	0.14	60400	84212	55318	71450	35336	
Tek Trol	1	2	16.5	16.8	12.8	7.50	0.03	85200	81857	53856	57050	27641	91.7%
Tek Trol	1	3	16.8	16.8	15.3	7.81	0.05	97800	81451	53243	61750	30678	91.7%
Tek Trol	1	10	16.3	17.6	12.8	7.87	0.06	91200	85680	56375	65250	25553	91.6%
Tek Trol	1	14	16.1	16.4	14.2	7.47	0.07	75200	84590	55970	60100	23310	91.5%
Tek Trol	1	21	13.1	15.6	12.8	7.60	0.07	96200	81848	53325	61000	19200	91.6%
Tek Trol	1	32	16	21.2	13.3	7.58	0.07	91600	86066	55850	65550	30577	91.2%
Tek Trol	1	40	18.6	19.0	12.8	7.76	0.04	97800	88343	57268	77550	27876	90.9%
Tek Trol	2	1	15.7	16.0	14.2	7.38	0.07	83200	82825	54465	59750	32906	
Tek Trol	2	2	15.9	16.0	14.4	7.51	0.04	61000	84040	55650	55800	29666	91.6%
Tek Trol	2	3	15.7	16.1	14.8	7.96	0.05	104400	83155	54933	67200	33007	91.5%
Tek Trol	2	10	15.0	17.4	14.3	7.51	0.04	86800	81710	53430	68100	25856	91.7%
Tek Trol	2	14	15.4	15.7	13.8	7.43	0.10	82800	87422	57956	59350	23432	91.4%
Tek Trol	2	21	11.9	15.2	11.8	7.45	0.08	101800	84676	55377	58000	21400	91.4%
Tek Trol	2	32	15.5	20.6	13.0	7.50	0.08	60400	90921	59803	85250	31590	90.9%
Tek Trol	2	40	17	17.9	13.0	7.52	0.05	103400	82145	52195	79250	31209	91.3%
Virkon	1	1	15.7	16.4	15.6	8.08	0.04	61600	77110	48680	46600	25110	
Virkon	1	2	16.2	16.8	15.6	8.14	0.05	102000	79916	51776	56050	24907	91.8%
Virkon	1	3	16.3	16.6	15.0	7.61	0.04	95800	79802	51677	62000	31691	91.9%
Virkon	1	10	16.2	18.0	15.6	7.69	0.07	72800	78182	49831	55600	18180	92.2%
Virkon	1	14	16.0	16.0	14.6	8.00	0.08	83600	79303	50815	66700	22932	92.0%
Virkon	1	21	14.3	15.9	13.2	7.69	0.09	90000	79372	50530	68300	20750	91.9%
Virkon	1	32	16	20.3	14.1	7.74	0.05	94800	79460	49117	52300	23186	92.0%
Virkon	1	40	17.6	18.1	14.4	7.91	0.02	91600	82573	50541	52000	23688	91.6%
Virkon	2	1	16.1	16.5	12.6	7.43	0.13	53600	79583	50620	29350	22983	
Virkon	2	2	16.1	16.8	15.6	7.78	0.02	78800	78120	50090	56100	26932	92.0%
Virkon	2	3	16.5	17.7	15.0	7.78	0.03	83600	78996	50568	67300	31691	91.9%
Virkon	2	10	16.3	18.0	15.8	7.89	0.04	87200	81467	52157	53650	14342	91.9%
Virkon	2	14	16.3	17.8	15.0	7.75	0.06	72600	83386	52758	49650	25326	92.0%

Table B4: Physical properties of the slurry recorded during the disinfectants experiment normalized by day 40.

Disinfectant	Replication	Days Post Dosing	Temperature	High Temperature	Low Temperature	pH (at time of sample)	Dissolved Oxygen	Chemical Oxygen Demand	Total Solids	Total Volatile Solids	Total Suspended Solids	Total Dissolved Solids	Moisture Content
Virkon	2	21	16.1	16.5	13.2	7.60	0.05	100400	79408	49713	61300	28000	91.6%
Virkon	2	32	16.1	21.2	14.1	7.87	0.04	61600	80956	49785	58100	24806	91.8%
Virkon	2	40	17.1	18.9	17.6	7.83	0.02	102000	80831	49492	59100	26563	91.3%

Table B5: Normalized nutrient content of the manure slurry from the disinfectant experiment.

Disinfectant	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	S	An	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
			ppm N	ppm N	ppm N	ppm N	ppm P2O5	ppm K2O	ppm S	ppm Ca	ppm Mg	ppm Na	ppm Zn	ppm Fe	ppm Mn	ppm Cu	ppm B	mmho/cm		%
Chlorine Bleach	1	1	3991.1	2951.6	2.2	6945	9189.2	3671.7	774.6	2385.9	2299.5	1079.6	214.7	265.9	56.1	47.4	3.9	26.45	7.6	7.61
Chlorine Bleach	1	2	4685.1	2357.2	0.7	7043	9099.4	3650.9	778.6	2374.2	2279.4	1083.2	215.6	265.6	55.4	46.8	3.9	25.84	7.6	7.49
Chlorine Bleach	1	3	5322.2	1822.8	1.9	7147	9269.5	3667.2	772.8	2421.2	2377.1	1087.6	215.9	270.7	56.3	47.9	3.9	26.46	7.6	7.54
Chlorine Bleach	1	10	2891.1	4071.8	1.2	6964	9468	3718.5	790	2472.9	2489.7	1098.3	223	272.2	56.7	48	3.3	25.35	7.7	7.56
Chlorine Bleach	1	14	3034	4235.6	1.3	7271	9482.6	3778.7	792.2	2497.6	2452.1	1115.6	221.3	276.8	57.8	48.6	4	27.08	7.6	7.66
Chlorine Bleach	1	21	3016.2	4382.7	1.1	7400	10307.8	4004.5	890.6	2821	2738.2	1193.5	243.1	293.2	62.5	53	3.5	24.51	7.5	8.02
Chlorine Bleach	1	32	2885.8	4390	1.1	7276.9	10170.4	4023	844.7	2677.1	2539.5	1175.7	234.2	285	61	51.6	4.5	27.58	7.7	7.87
Chlorine Bleach	1	40	3241	4404.1	1	7646.1	10774.1	4256	931.5	2897.9	2712.9	1254.7	255.7	313.6	66.1	56.2	4.5	26.64	7.6	8.26
Chlorine Bleach	2	1	3315.7	3959.2	1.2	7276.1	9398.1	3673.6	792.8	2481.9	2456.6	1091.8	219.3	268.8	56.6	47.7	3.1	27.04	7.6	7.5
Chlorine Bleach	2	2	3799.5	3346.2	0.9	7146.6	9405.6	3704.2	781.1	2488.9	2439	1094.6	219.4	267.5	56.6	48.7	3.4	27.1	7.6	7.47
Chlorine Bleach	2	3	4001.4	3395.3	0.7	7397.4	9363.4	3684.5	829.7	2506.7	2330.6	1089.1	222.1	260.8	57.5	49.9	3.9	26.3	7.7	7.79
Chlorine Bleach	2	10	4381.7	2811.2	0.2	7193.1	9613.8	3846	805.6	2579.9	2464	1142.9	224.7	284.4	58.8	49.3	3.9	26.86	7.6	7.52
Chlorine Bleach	2	14	3311.9	4004.2	0.9	7317	9806.3	3891.4	851.4	2651	2552.1	1113.7	230.7	293.5	59.4	50.5	3.7	26.04	7.5	7.79
Chlorine Bleach	2	21	4376.4	2935.2	2.4	7314	10031.4	3943	855.4	2755.7	2522.4	1164.7	237.5	277.5	61.4	52.7	4.4	26.63	7.5	7.94
Chlorine Bleach	2	32	3603.4	3924.5	2	7529.9	10394.2	4128.7	881.8	2801.9	2647.5	1222	241.9	306.1	63.4	53.6	4.3	26.97	7.6	7.9
Chlorine Bleach	2	40	3918.4	3576.3	2.2	7496.9	10702.6	4282.1	911.2	2837.3	2703.3	1261.9	250.5	301	64.8	55.2	4.8	26.74	7.7	8.17
Control	1	1	3716.9	3658.7	3.4	7379	9166.5	3625.8	779.5	2347.4	2231.6	946.8	213.4	257.7	55.8	47.4	4	26.38	7.7	7.56
Control	1	2	3245	3934.7	1.2	7181	9296.7	3674.2	787.7	2576.9	2369.2	970.3	215.8	273.7	56.4	47.5	3.6	27.08	7.6	7.5
Control	1	3	3730.6	3564.4	1.6	7296.6	9513	3772.6	836.9	2472.9	2299.9	973.6	221.3	269.4	57.9	49.9	4.3	25.86	7.6	7.77
Control	1	10	3470.2	3735.1	1.1	7206.4	9643.7	3809	852.2	2533.9	2447.6	1003.2	229.5	285.6	58	49.9	3.9	26.5	7.7	7.63
Control	1	14	3517.8	3729.5	0.9	7248.2	9730.9	3787.7	830.8	2622.6	2555.4	999.8	227.1	298.7	58.6	50	3.8	26.18	7.6	7.67
Control	1	21	3610.5	3707.1	2.5	7320.1	9629.7	3846.7	810.8	2508.2	2337.2	1001.4	225	271.4	58.1	49.6	4.6	25.93	7.6	7.77
Control	1	32	5406.4	2365.3	12	7783.8	10136.8	4012	862.7	2712.9	2460.8	1049.1	236.9	289.9	61.4	52.2	4.6	26.5	7.6	7.94
Control	1	40	4375.7	3278	2	7655.7	11096.5	4312.7	973.3	2983.6	2794.9	1129.5	261	326.8	66.9	57.2	4.8	26.97	7.7	8.28
Control	2	1	3895.2	3264.3	1.4	7160.9	9331.4	3695.8	776.3	2415.2	2178.3	952.9	210.8	273.5	56.7	47.7	4.3	26.44	7.6	7.8
Control	2	2	3698.8	3471.4	1.2	7171.4	9411.5	3675.3	789.2	2469.6	2350.9	968.1	219.6	289.8	56.7	47.9	4	26.34	7.6	7.73
Control	2	3	4954.6	2354.1	7.4	7316.1	9509.1	3703.2	822.1	2480.4	2239.5	961.6	217.4	274.4	57.5	48.9	4.3	26.05	7.6	7.97
Control	2	10	3831.1	3354.1	2	7187.2	9579.8	3692.1	794.6	2448.9	2386.7	974.9	219.5	266.2	56.9	47.4	3.9	26.38	7.6	7.79
Control	2	14	4023.1	3042	7.1	7072.2	9806.5	3799.5	805.6	2598.8	2503.4	1008.8	228.1	288.3	59.2	49.4	4	26.57	7.5	7.81
Control	2	21	3858.6	3392.5	3.8	7254.9	10240.3	3877.9	875.4	2784.5	2589.4	1021.7	236	300	61.8	52.3	3.9	25.37	7.5	8.22
Control	2	32	3983.5	3362.6	3.4	7365.8	10499	4157.2	870.9	2736.4	2467	1072.9	236	291.6	63.5	53.2	4.9	25.9	7.6	8.15
Control	2	40	3586.7	3954.9	3	7544.5	11228.8	4359.9	989.4	3053.2	2643.9	1135.9	258.3	318.5	68.7	58.1	5.2	25.86	7.6	8.7
Pi-Quat	1	1	3561.9	3529.3	2.8	7094	9424.1	3708.7	795.6	2496.9	2462.1	976.7	220.6	283.3	56.8	49.1	3.7	26.41	7.6	7.77
Pi-Quat	1	2	4297.2	3101.5	2.3	7401	9492.2	3687.6	799.5	2535.6	2533	974.2	227.3	310.8	57	47.3	3.2	26.03	7.6	7.69
Pi-Quat	1	3	3675.2	3555.1	3.7	7234	9081.8	3615	773.9	2378.1	2241.9	947.1	213.9	256.8	55.2	46.8	4.1	26.25	7.6	7.85

Table B5: Normalized nutrient content of the manure slurry from the disinfectant experiment.

Disinfectant	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	S	An	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
Pi-Quat	1	10	3611.7	3250.6	2.7	6865	9568.3	3702.2	807.6	2524.2	2492.2	986.5	222.5	288.8	56.7	48.3	3.8	26.46	7.6	7.86
Pi-Quat	1	14	4238.2	2796	3.8	7038	9697.6	3763.7	787.3	2551.1	2522.9	985.5	226.4	281	57.7	49	3.5	26.27	7.6	7.93
Pi-Quat	1	21	4627.9	2679.4	2.7	7310	9646.4	3852	795.4	2560.2	2456.1	1016.3	226.7	291	58.7	49.9	4.1	25.25	7.6	8.13
Pi-Quat	1	32	3829.2	3341.5	4.3	7175	10131.2	4103	829	2678.3	2329.1	1073.9	229.6	287.1	61.9	53.1	4.7	24.2	7.6	8.45
Pi-Quat	1	40	3606.7	3150	4.3	6761	10443.6	4125.1	859.4	2718.2	2504.4	1085.3	241.6	297	62.5	52.9	4.7	23.74	7.6	8.81
Pi-Quat	2	1	3646.8	3440.8	2.3	7090	9289.1	3741.9	784.8	2479	2400	1005.9	216.3	284.6	56	47.6	3.8	25.95	7.6	7.57
Pi-Quat	2	2	4361.3	3029.4	2.3	7393	9145.1	3700	784.8	2421.6	2302.6	971.1	215.3	281.8	55.6	46.8	3.8	26.34	7.6	7.54
Pi-Quat	2	3	3664.1	3803.8	3.1	7471	9276.3	3765.8	791.2	2476.5	2272.9	976.2	215.5	262.1	56.5	47.9	4.4	26.79	7.6	7.67
Pi-Quat	2	10	3187.1	3714	2.9	6904	9344.5	3728.3	793	2486.9	2399.4	978.8	220.3	278.5	55.8	47.1	3.8	27.02	7.6	7.82
Pi-Quat	2	14	2828.8	4333	1.2	7163	9367.5	3786	783.2	2581.2	2421.5	990.6	217.9	276.2	56.8	48.6	3.9	26.29	7.6	7.78
Pi-Quat	2	21	3010.8	4131.4	1.8	7144	9459.8	3869.6	786	2495.4	2325.3	999.6	221.9	273.1	57.8	48.9	4.3	25.76	7.6	8.03
Pi-Quat	2	32	3189.3	3822.9	1.9	7014	10298	4022.4	862.2	2804.1	2777.6	1077.6	244.5	327	61.2	52.1	3.2	24.84	7.6	8.42
Pi-Quat	2	40	3566.9	3411.6	1.5	6980	10655.2	4319	879.8	2809.9	2634.7	1128.5	251.7	306.7	65	55	4.6	23.5	7.6	8.76
Tek Trol	1	1	3379.5	3699.7	1.9	7081.1	9176	3715.6	802.8	2412.3	2271.8	1006.8	215.4	254.6	55.5	46.8	4.1	26.27	7.7	7.85
Tek Trol	1	2	3973.2	2895.6	1.3	6870.1	9229.1	3756.3	816.8	2427	2420.1	1027.3	219	273.2	56.2	47.8	3.4	26.09	7.8	7.78
Tek Trol	1	3	3565.7	3290.9	1.1	6857.7	9285.7	3773.9	817	2448.8	2468.4	1030.9	218.1	270.8	56.4	47.5	3.2	26.64	7.7	7.83
Tek Trol	1	10	3835.4	3124	2.5	6961.9	9236.5	3840.9	798.2	2451.7	2193.1	1032.8	210.8	257.5	56.9	48.6	4.3	25.92	7.7	7.89
Tek Trol	1	14	4020.4	2934.9	2.4	6957.7	9382.4	3777.8	801.8	2457.9	2332.1	1029.9	216.3	280.9	56.5	47.9	4	25.76	7.7	7.95
Tek Trol	1	21	4527.1	2520.3	2.5	7049.9	9772.1	3902.2	847.4	2631.1	2536	1097.5	227.7	294	58.6	50.2	3.7	25.83	7.6	8.17
Tek Trol	1	32	3415.7	3607.3	2.6	7025.6	10652.9	4168.3	923.4	2854.4	2948.2	1149.4	251.7	322.4	63	52.8	6.3	24.51	7.6	8.46
Tek Trol	1	40	3347.9	3652.3	2.2	7002.4	10748.4	4343.5	938.5	2848.6	2729.6	1183.7	252.2	319.7	64.6	54.9	4.6	24.42	7.7	8.78
Tek Trol	2	1	2763	4594.7	2.2	7360	9531.2	3769.4	851.3	2504.3	2518.1	1030.7	224.1	301.5	56.5	47.5	3.3	26.61	7.8	7.87
Tek Trol	2	2	2624.2	4700.2	2.4	7326.9	9129.3	3728.3	801	2397	2228.1	997.2	214.1	268.9	55.3	46.9	4.2	26.06	7.7	7.85
Tek Trol	2	3	2953.9	4366.7	1.6	7322.2	9491.7	3827.1	841	2492.6	2474.9	1034.8	221.4	289.2	56.8	48	3.6	26.27	7.8	7.93
Tek Trol	2	10	3739.6	3591.5	2.5	7333.6	9417.6	3818	841.3	2483.9	2393.2	1033.6	220.4	277.3	57.1	47.7	4.1	25.8	7.6	7.95
Tek Trol	2	14	3146.7	3893	2	7041.7	9552.1	3948.8	820.2	2526.7	2392.9	1063.9	224	279.6	58.8	50.1	4.2	25.62	7.8	8.05
Tek Trol	2	21	3498.2	3527	2.3	7027.5	9787.9	3970.5	854.3	2570.4	2420.3	1071.8	228.1	287.9	59.3	49.8	4.3	25.19	7.6	8.19
Tek Trol	2	32	3009.6	4012.8	2.5	7024.8	10136.9	4108.3	888.3	2680.4	2612.2	1113.1	238.9	316.1	61.1	51.5	4	24.42	7.7	8.56
Tek Trol	2	40	3777.7	3074.4	1.8	6854	10971.1	4370.3	957.8	2974.3	2921.9	1209.1	256.4	331.1	65.1	54.6	3.1	24.4	7.8	8.86
Virkon	1	1	2235.8	4751.4	0.8	6988	9579.5	3694.7	815.8	2639.7	2653.9	988.9	225.6	283.5	58.1	49.7	5.7	25.33	7.5	7.58
Virkon	1	2	3010.8	4282.6	0.6	7294	9091.2	3640.2	744.3	2339.5	2211.3	938.2	210.3	262.7	55.4	46.8	4	26.29	7.5	7.49
Virkon	1	3	2770	4545	1	7316	9098	3601.8	777.1	2333.6	2278.4	939.3	212.9	251.9	55.5	47.1	3.9	27.64	7.7	7.65
Virkon	1	10	4363.6	2788.4	1	7153	9101.5	3719.4	763.2	2319.1	2206.9	956.4	211.3	255	56.3	47.3	4.2	27.02	7.7	7.62
Virkon	1	14	3581.6	3320.6	0.8	6903	9384.2	3654.5	805.3	2456.8	2496	965.3	217.3	267	57.4	47.6	3.1	26.54	7.5	7.68
Virkon	1	21	4301	2833.3	0.7	7135	9482.7	3836.7	809.6	2536.5	2335.3	1005.1	225.2	260.8	59.2	50.8	4.2	26.39	7.5	7.71
Virkon	1	32	3642.4	3710.6	1	7354	10127.1	4064.1	845.7	2642.2	2378.6	1058.7	229.3	283.6	62.1	51.8	4.6	26.47	7.6	7.82
Virkon	1	40	5005.4	2422.7	0.9	7429	10972.5	4327	993.6	2943.8	2696.4	1132.6	262.8	316.5	67.3	58.1	4.7	26.86	7.6	8.3

Table B5: Normalized nutrient content of the manure slurry from the disinfectant experiment.

Disinfectant	Replication	Days Post Dosing	Org. N	NH3-N	NO3-N	Tot. N	P	K	S	Ca	Mg	S	An	Fe	Mn	Cu	B	Soluble Salts	pH	Dry Matter
Virkon	2	1	6002.4	1119.6	1.1	7123	9471.5	3629.1	791.1	2467	2448	957.2	218	267.5	57.5	47.5	3.9	27.17	7.6	7.67
Virkon	2	2	4685.3	2725.1	0.6	7411	9540.1	3652.3	794.2	2524.8	2566	969.5	224	270.6	57.6	48.9	3	26.13	7.5	7.62
Virkon	2	3	5068.5	2238.5	1	7308	9631.4	3726.1	808.3	2494.7	2453.3	983.2	227.1	279.8	58.8	49.8	4	25.36	7.6	7.69
Virkon	2	10	4750.4	2506.1	1.5	7258	9728.9	3752.7	795.5	2490.4	2437.3	984	225	270.8	58.7	49.4	4.3	26.85	7.7	7.68
Virkon	2	14	3979	3251.2	0.7	7231	9744.6	3769.7	815.5	2592.1	2474.6	989.2	227.2	274.1	59	49.8	4.3	25.7	7.5	7.7
Virkon	2	21	4369.4	3113.6	1.1	7484	10520.7	3913.7	914.4	2918.4	2726.1	1049.4	251.7	296.5	63.7	54.5	3.6	26.82	7.5	8.08
Virkon	2	32	5326.2	2240.8	2	7569	10516.8	4154	864.3	2798.1	2450.4	1092.8	237.4	285.7	65	55.1	4.7	27.26	7.6	7.99
Virkon	2	40	5167	2716.1	2.8	7886	11652.3	4399.2	1057.8	3105.3	2927.8	1165.6	278.9	341.9	70.1	60	4.3	26.77	7.6	8.53

Table B6: Normalized antibiotics slurry concentrations for the disinfectants experiment

Disinfectant	**Replication**	**Days Post Dosing**	Chlortetracycline	Lincomycon	Tiamulun	Oleandomycin Recovery
Chlorine Bleach	1	1	0.812	0.239	0.551	0.639
Chlorine Bleach	1	5	0.465	0.496	0.319	0.600
Chlorine Bleach	1	14	0.789	0.228	0.232	0.366
Chlorine Bleach	1	21	0.880	0.445	0.966	0.934
Chlorine Bleach	1	40	1.000	1.000	1.000	1.000
Chlorine Bleach	2	1	1.273	0.820	0.378	0.475
Chlorine Bleach	2	5	0.454	0.407	0.220	0.548
Chlorine Bleach	2	14	0.820	0.384	0.274	0.332
Chlorine Bleach	2	21	0.846	1.461	0.770	0.661
Chlorine Bleach	2	40	1.000	1.000	1.000	1.000
Control	1	1	1.172	0.098	0.231	0.714
Control	1	5	0.602	0.088	0.250	0.506
Control	1	14	0.814	0.491	0.384	0.840
Control	1	21	1.068	0.592	1.125	1.098
Control	1	40	1.000	1.000	1.000	1.000
Control	2	1	0.868	0.175	0.229	0.943
Control	2	5	0.934	1.173	0.438	0.621
Control	2	14	0.515	0.056	0.414	0.617
Control	2	21	0.948	0.087	0.800	1.453
Control	2	40	1.000	1.000	1.000	1.000
Pi-Quat	1	1	0.650	0.187	0.448	0.955
Pi-Quat	1	5	1.146	1.400	0.538	0.892
Pi-Quat	1	14	0.873	4.727	0.574	0.607
Pi-Quat	1	21	1.100	5.155	0.847	1.454
Pi-Quat	1	40	1.000	1.000	1.000	1.000
Pi-Quat	2	1	0.651	0.814	0.978	1.104
Pi-Quat	2	5	0.286	1.094	0.582	0.268
Pi-Quat	2	14	0.675	0.995	0.914	0.636
Pi-Quat	2	21	0.692	0.650	1.369	1.299
Pi-Quat	2	40	1.000	1.000	1.000	1.000
Tek Trol	1	1	1.591	0.806	0.744	1.147
Tek Trol	1	5	0.418	0.684	1.025	1.097
Tek Trol	1	14	1.220	1.658	1.256	8.529
Tek Trol	1	21	1.459	0.492	3.757	11.771
Tek Trol	1	40	1.000	1.000	1.000	1.000
Tek Trol	2	1	1.004	0.918	0.564	1.497
Tek Trol	2	5	24.034	1.940	0.393	1.440

Table B6: Normalized antibiotics slurry concentrations for the disinfectants experiment

Disinfectant	**Replication**	**Days Post Dosing**	Chlortetracycline	Lincomycon	Tiamulun	Oleandomycin Recovery
Tek Trol	2	14	1.062	2.672	1.026	1.268
Tek Trol	2	21	1.164	0.477	2.391	2.415
Tek Trol	2	40	1.000	1.000	1.000	1.000
Virkon	1	1	0.753	0.138	1.038	0.667
Virkon	1	5	0.109	0.646	0.230	0.533
Virkon	1	14	0.816	0.230	0.439	0.396
Virkon	1	21	0.680	1.039	0.606	1.501
Virkon	1	40	1.000	1.000	1.000	1.000
Virkon	2	1	0.684	0.170	0.351	0.886
Virkon	2	5	0.538	0.611	0.400	0.967
Virkon	2	14	0.708	1.661	0.363	0.644
Virkon	2	21	0.875	0.855	1.462	1.433
Virkon	2	40	1.000	1.000	1.000	1.000